HYDROLOGIC AND HYDRAULIC ASSESSMENT OF CHOATE BROOK BRIDGE

EVERETT LAKE
WEARE, NEW HAMPSHIRE

SUBMITTED TO:

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
424 TRAPELO ROAD
WALTHAM, MASSACHUSETTS

SUBMITTED BY:

HYDRAULIC & WATER RESOURCES ENGINEERS, INC.
1345 Main Street
Waltham, MA 02154

CONTRACT NO. DACW 33 – 92 – D – 0003

OCTOBER 1993

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CHOATE BROOK BRIDGE, EVERETT LAKE
WEARE, NEW HAMPSHIRE

1.0 INTRODUCTION

This report presents a hydrologic and hydraulic assessment of scour potential conducted under the New England Division, Corps of Engineers' Bridge Inspection Program for Choate Brook Bridge in the Everett Lake area in Weare, New Hampshire. The scour analyses were performed in accordance with Department of Transportation, Federal Highway Administration (FHWA) guidance. The analyses include: determination of scour critical flows and velocities, estimation of maximum potential scour depth, and recommendations for minimizing or preventing further scour at the bridge.

2.0 PROJECT DESCRIPTION

2.1 Location

The project site is located in the town of Weare in south central New Hampshire on Choate Brook, a tributary of the southeasterly flowing Piscataquog River (Figures I and II). Choate Brook Bridge is in the northern portion of Everett Lake and about 1300 feet from the Piscataquog River channel. The bridge is within the area of Hopkinton - Everett Reservoirs and can be accessed from River Road via Bassett Mill Road.

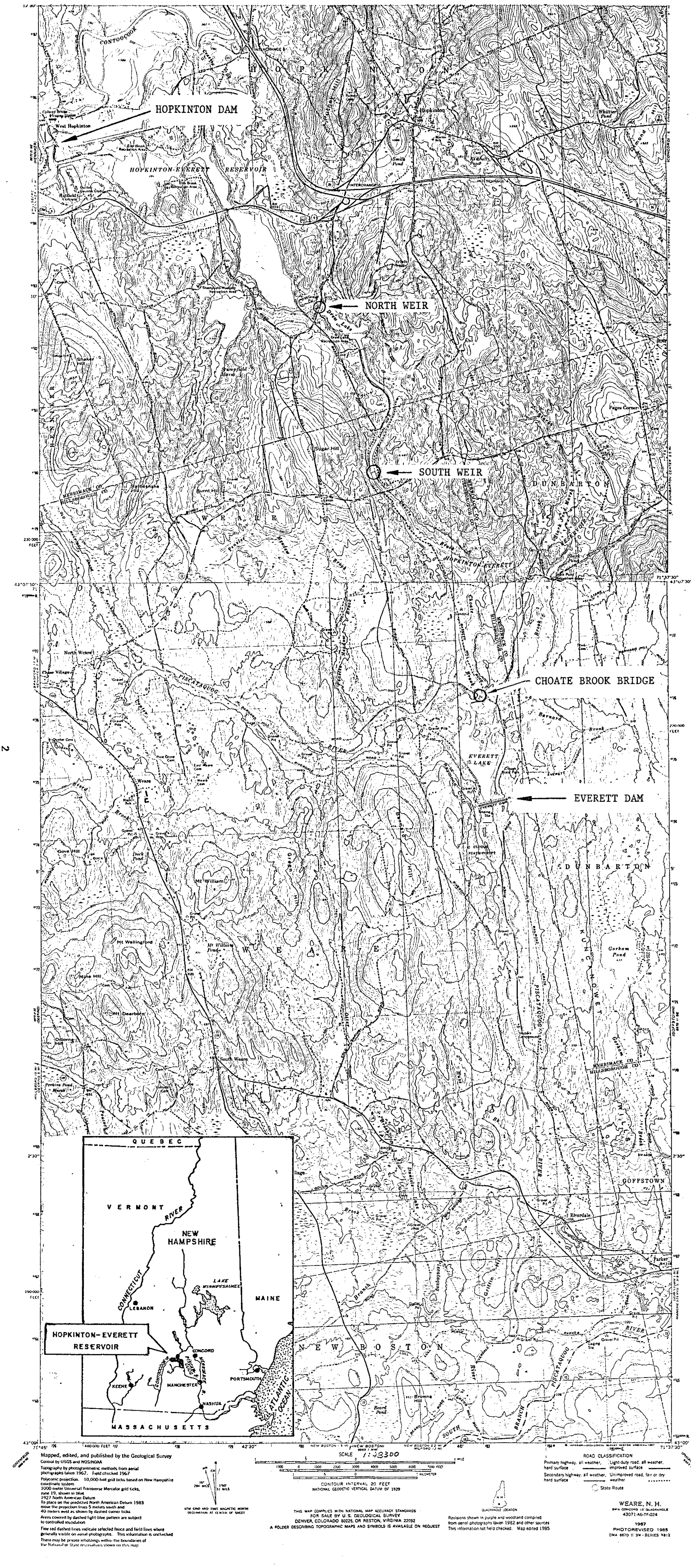


Figure I Locus Map

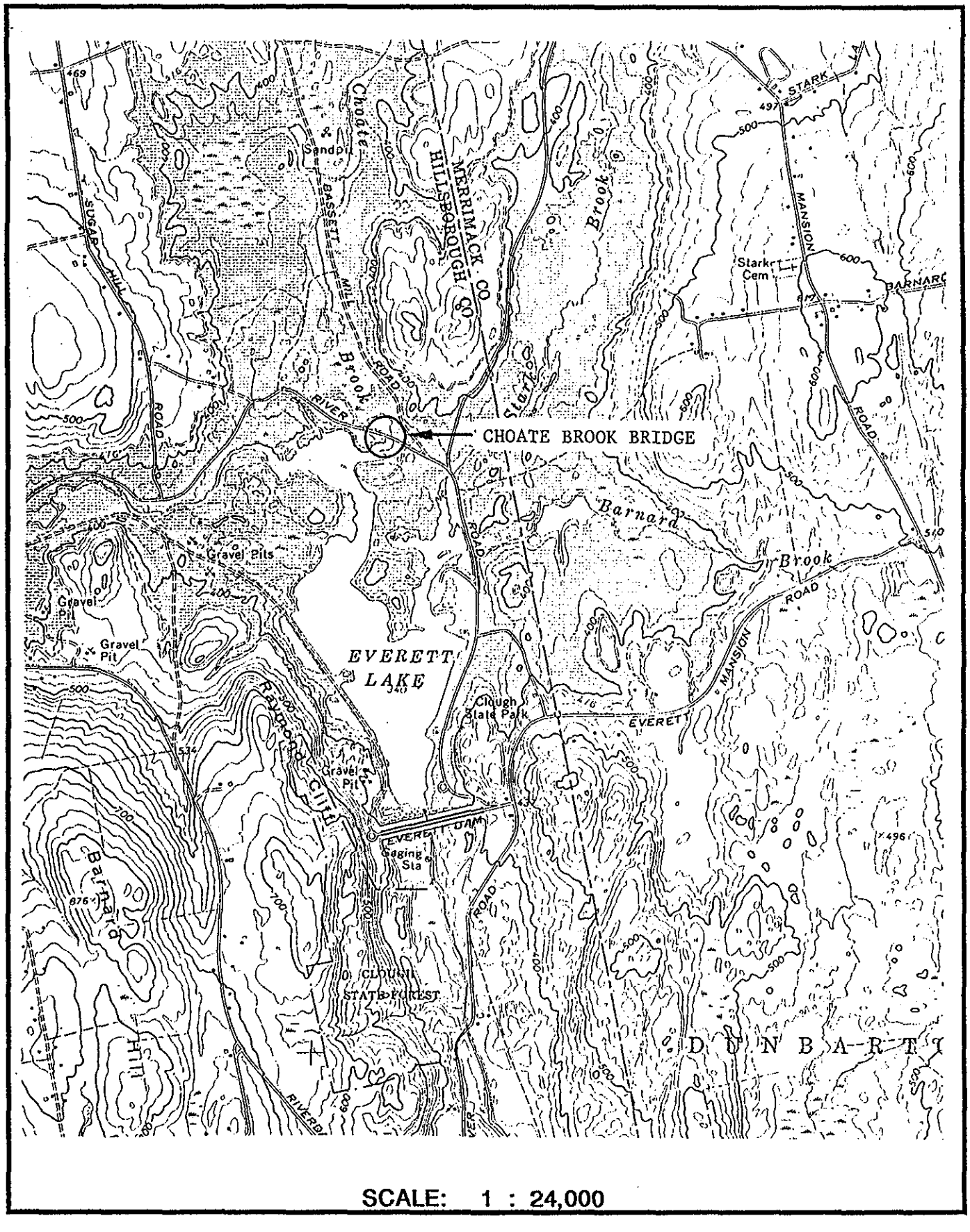


Figure II Enlarged Location Map for Choate Brook Bridge

2.2 Site Conditions

Choate Brook generally runs southeasterly in its upper watershed but southwesterly through the bridge area towards Everett Lake. The brook forms fairly large ponds on both upstream and downstream sides of the bridge with fairly flat banks. A moderate sloping hill ascends to the west of the bridge. The embankment is much higher and steeper on the right bank than on the left bank. There is no sign of significant erosion over the embankment. The bridge is skewed about 15° clockwise with flow direction. According to the Corps of Engineers (Geotechnical Assessment, September 1993), Choate Brook is situated in a low, flat and relatively wide area in the pre-glacial Piscataquog River Valley. The valley is filled with deep glacial outwash deposits and till. The stream eroded a narrow valley in the outwash deposits and till. Till and till-covered bedrock hills which rise above the lowlands form the perimeter of the stream's drainage area. Choate Brook is slightly meandering with medium to dense vegetation, brushes and trees over the banks. Photos 1 to 4 are views of the bridge and the stream in the vicinity of the bridge.

The streambed consists of clean, fine to coarse sand and gravel with rounded to subangular cobbles and boulders. The mean diameter of sand to boulders on the streambed was estimated to be from 0.3 to 0.5 feet by visual observation during our site visit (July 8, 1993). This estimation is about the same as the Corps of Engineers' estimation. The Corps of Engineers recently conducted a gradation analysis of the sand and gravel matrix which exists between cobbles and boulders and reported in the

Photo #1 Choate Brook Bridge, Upstream Face

Photo #2 Choate Brook Bridge, Downstream Face

Photo #3 Choate Brook Bridge, Upstream View from Bridge

Photo #4 Choate Brook Bridge, Downstream View from Bridge

September 1993 Geotechnical Assessment that the mean diameter, D_{50}, by weight of the sand and gravel matrix is 1.5 millimeters (mm).

According to the Corps of Engineers' FY-91 Bridge Inspection Program report, Choate Brook Bridge has a concrete slab deck which bears on rubble masonry abutments and footings (Figures III and IV). A smooth concrete surface has been cast against the right abutment. The abutments and footings appear to be in fair to good condition. Corners of the bridge abutments are protected by stone revetment. The outer layer of the revetment is in good condition. However, it does not appear that there are filter layers between the outer layer and the subgrade.

The footings of the bridge are founded on sand and gravel. It appears that high velocities have scoured the sand and gravel below the downstream end of the right abutment footing (Photos 5 and 6). The scour hole is approximately five feet by two feet and is up to two feet deep as reported in the Corps of Engineers' Geotechnical Assessment. Distress cracks were not noted in the abutment area above the scour hole.

According to the geotechnical assessment report, small repairs have been made recently to the footings, revetments, and abutments. An apparent scour hole under the upstream end of the right abutment footing was filled with concrete. Voids between the stones in the top two feet of the left abutment were filled with grout. Voids in the stone

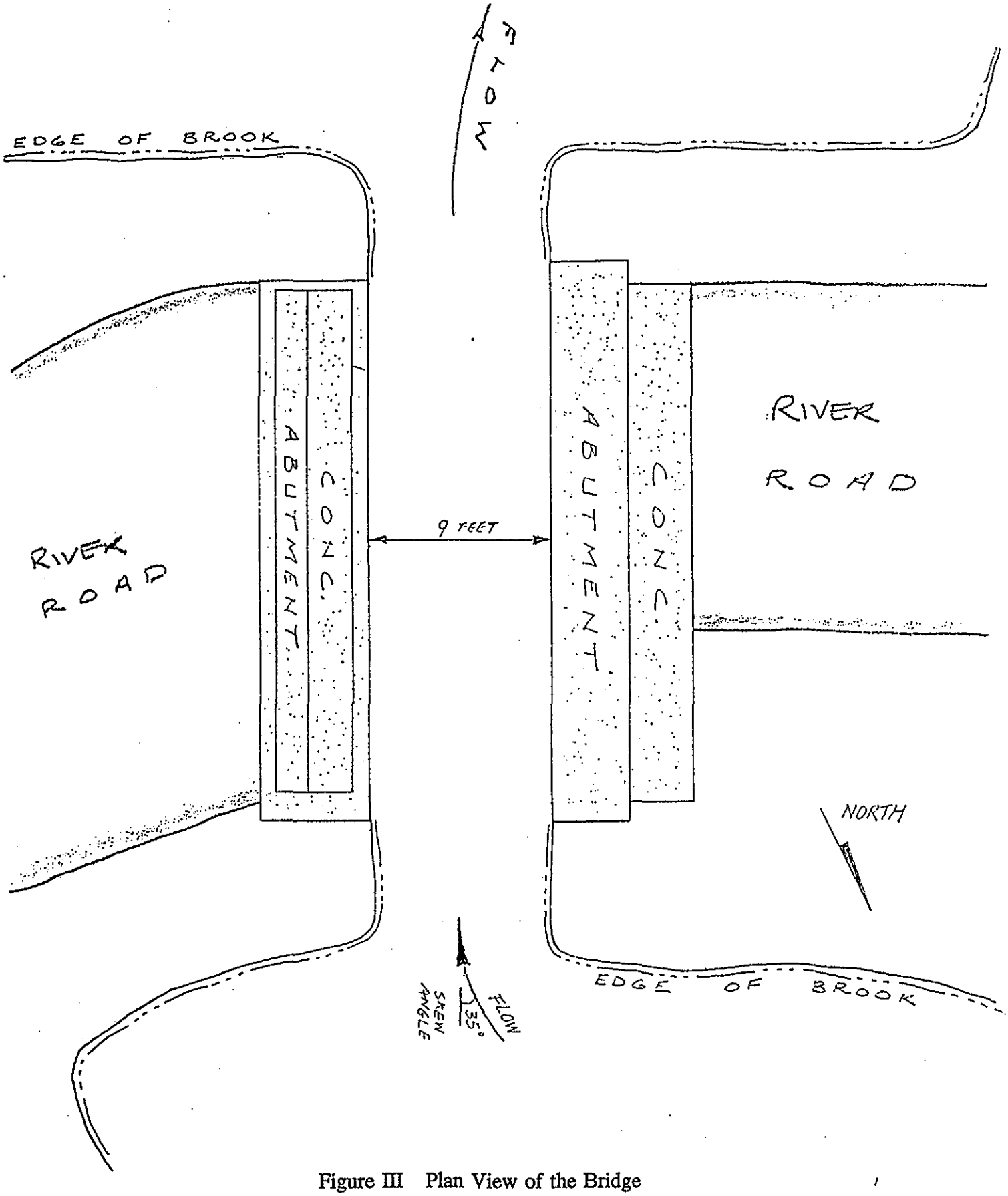


Figure III Plan View of the Bridge

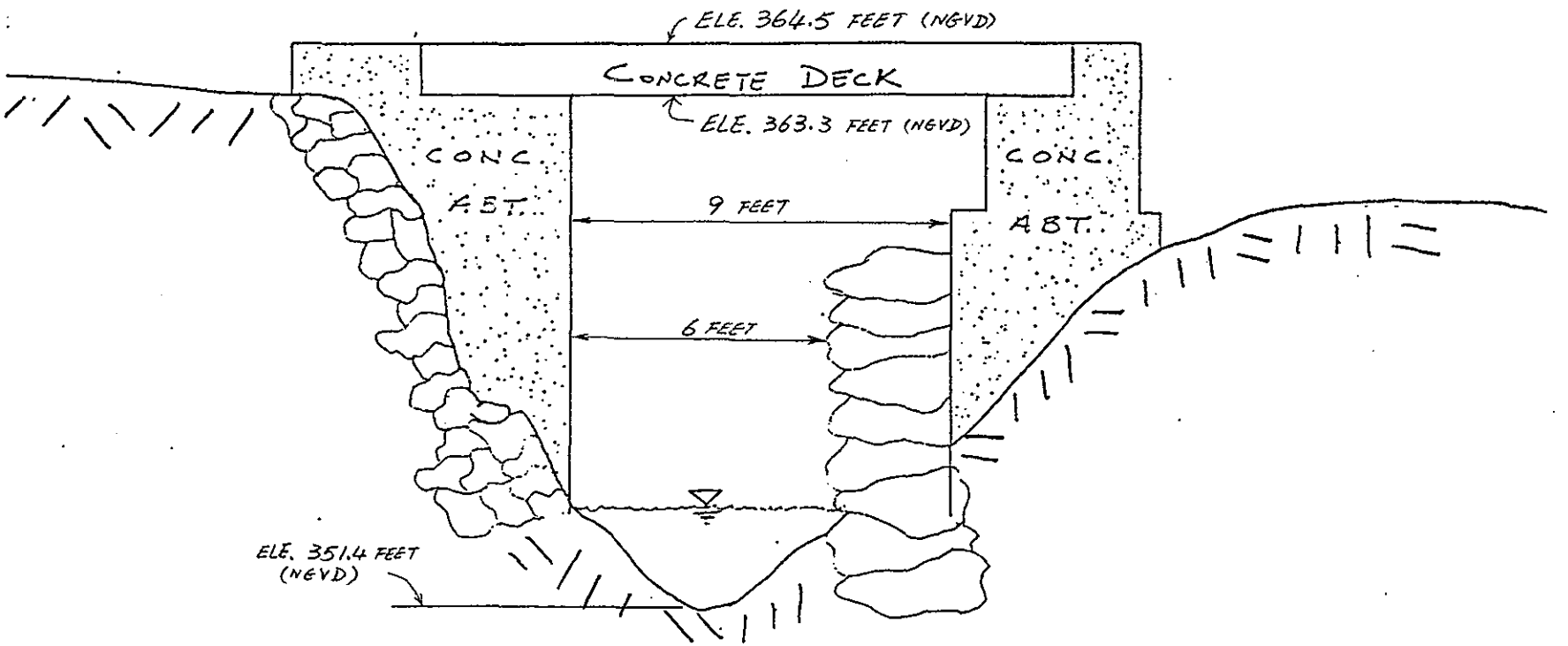


Figure IV Vertical View of the Bridge (looking upstream)

Photo #5 Choate Brook Bridge, Upstream End of the Right Abutment

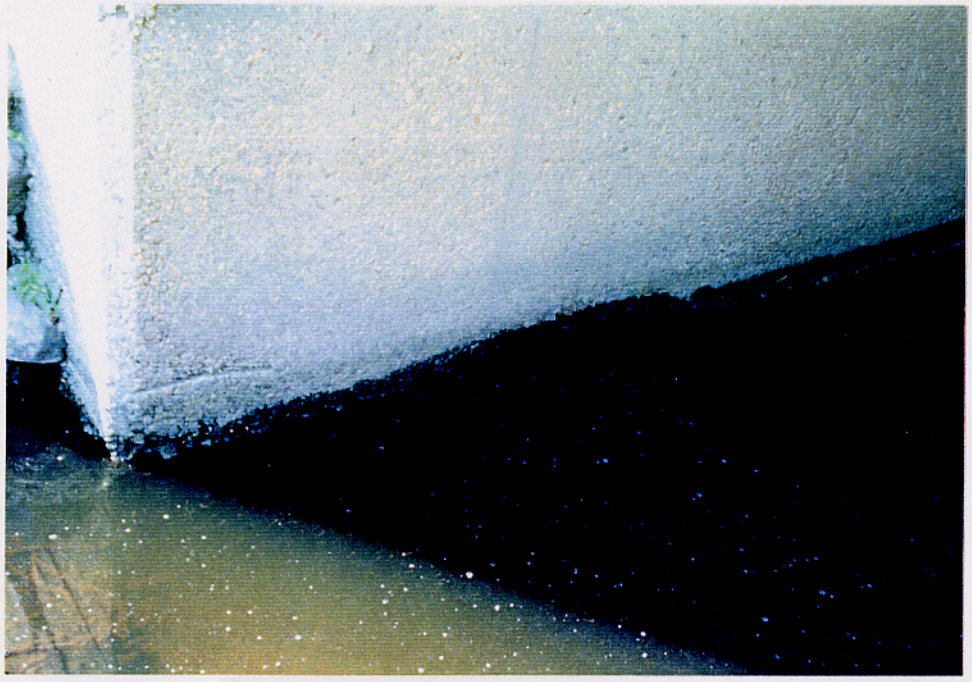


Photo #6 Choate Brook Bridge, Downstream End of the Right Abutment

revetments at the upstream end of the bridge were filled with grout. Generally, the work looks good except that an area up to three feet wide was not grouted at the junction of the stone revetment and the left upstream corner of the bridge.

3.0 HYDROLOGIC ANALYSIS

3.1 General

The Hopkinton-Everett Reservoir system is operated primarily as a component of a coordinated system of reservoirs for flood control in the Merrimack River Basin. The reservoirs are in Merrimack and Hillsborough counties in New Hampshire. Hopkinton Dam is on the Contoocook River 17.3 miles above its confluence with the Merrimack River and one-half mile upstream from the village of West Hopkinton. Everett Dam is on the Piscataquog River, about 1.3 miles southeast of East Weare.

Hopkinton Reservoir has a total drainage area of 382 mi^2. Hopkinton Dam has a length of 790 feet with its top elevation at 437 feet N.G.V.D.. The inlet elevation of the reservoir's outlet works is 366 feet N.G.V.D.. The spillway has a crest length of 300 feet and crest elevation at 416 feet N.G.V.D., with a maximum discharge capacity of 135,000 cubic feet per second (cfs). The reservoir, when filled to spillway crest, has a total storage capacity of 70,800 acre-feet covering a surface area of about 3,700 acres.

Everett Reservoir has a drainage area of 64 mi^2. Everett Dam has a length of 2,000 feet with its top elevation at 435 N.G.V.D.. The inlet elevation of the reservoir's outlet

works is 325 feet N.G.V.D.. The spillway has a crest length of 175 feet and crest elevation at 418 feet N.G.V.D. with a maximum discharge capacity of 68,000 cfs. The reservoir when filled to spillway crest has a total storage capacity of 92,500 acre-feet covering a surface area of about 2,900 acres. Choate Brook Bridge, with a low chord at an elevation of 363.30 feet N.G.V.D. and a top elevation of 364.55 feet N.G.V.D., would be completely submerged when Hopkinton Reservoir and/or Everett Reservoir are filled to their spillway crest elevations.

3.2 Characteristics of Choate Brook Drainage Area

Choate Brook is a bypass channel for the diversion of flow from Hopkinton Reservoir to Everett Reservoir during periods of significant storage. When the water level in the Hopkinton Reservoir exceeds the north weir crest (400.5 feet N.G.V.D.), flow is diverted to Drew Lake and to the south weir through Canal No. 2. According to August 1992 Corps of Engineers' survey, crest elevation of the south weir is approximately 401.1 feet N.G.V.D. (see Scope of Work). As water level reaches 401.1 feet N.G.V.D., flow will pass over the south weir to Choate Brook and enter Everett Reservoir.

During normal operations, Drew Lake drains in two opposite directions: north flowing water passes through a stop log structure in the north weir to Hopkinton Reservoir and south flowing water passes through a culvert located in the south weir to Choate Brook and then to Everett Reservoir. The drainage area from the north weir to Choate Brook

Bridge is 6.6 square miles. Locations of the bridge, weirs and reservoirs are shown in Figure I.

3.3 Peak Discharges

There is a gaging station on Contoocook River immediately downstream from Hopkinton Dam and another gaging station on Piscataquog River immediately downstream from Everett Dam. Choate Brook is ungaged. Peak discharges at Choate Brook Bridge were determined based on the following conditions: (1) a localized storm over the Choate Brook drainage basin during normal reservoir operations and (2) flows caused by diversion of flood from Hopkinton Reservoir to Everett Reservoir.

Condition 1:

Choate Brook peak discharge - frequency relationships were established at the bridge site by using regional equations for estimating peak discharges on rural, unregulated streams in watershed of similar size and location (USGS - Water - Resources Investigations 78-47). The floods that can be expected to occur for Condition 1 at the bridge site with exceedence probabilities of 0.1 to 0.01 were determined and presented in a tabular form (refer to Table I). The average standard errors of the estimations are also included in the table.

TABLE I

Discharges at Various Exceedence Probabilities

Exceedence Probability	Estimated Peak Discharge at Bridge Site (cfs)	Error in Percentage
0.10	159	44
0.04	209	50
0.02	242	54
0.01	283	58

Condition 2:

During most reservoir operations in which flow overtops the south weir, Choate Brook Bridge is already inundated by high pool stages at Everett Reservoir. In some cases, however, the Everett pool may be below the bridge during initial weir overtopping. Therefore, scour potential will be evaluated at the bridge assuming low tailwater conditions for flow rates of 610 cfs and 1820 cfs. These flow rates correspond to about 1 and 2 feet of energy head above the south weir crest, respectively.

3.4 Tailwater Conditions

Although backwater during most reservoir operations, in which the south weir is submerged, can seriously impact flow conditions at the bridge site, such tailwater conditions do not necessarily correspond to specific peak flows in Choate Brook. Flow in Choate Brook could peak well before water elevations in Hopkinton and Everett

Reservoirs reach peak pool levels because the brook's drainage area is about 2 order of magnitude smaller than the drainage areas of the reservoirs.

The lowest tailwater for a specific flow is the most critical condition for bridge scour analysis. Therefore, backwater effect from Everett Lake is assumed to be negligible in order to develop the most critical scour velocities.

4.0 HYDRAULIC ANALYSES

4.1 Backwater Analysis

A backwater analysis was performed at the bridge site using the "BOSS - WSPRO" model for water surface profile computations (BOSS - WSPRO User's Manual and FHWA/RD-86/108). Seven cross sections in the vicinity of the bridge were used for the computations (refer to the figure in Appendix B). Locations of the cross-sections were determined based on the U.S.G.S. topographic quadrangle map of Weare, New Hampshire, 1967, and our site visit on May 7, 1993. Geometric data of the cross-sections were obtained by our survey crew during the period of July 8 to July 13, 1993. Water surface elevations and flow velocities for the 10, 25, 50, 100 - year frequency floods, and the two discharges, 610 cfs and 1820 cfs, were computed respectively.

The values of Manning's roughness coefficients for the main channel and overbanks were determined to be 0.02 and 0.05, respectively. These values were obtained based on mean bed material size and vegetation conditions under the guidance given in the U.S.G.S.

Water Supply Paper (#2339). Coefficients for expansion loss and contraction loss were assumed to be 0.5 and 0.1 respectively. Output from WSPRO showed that the conveyance ratios for sections 1030, 1080 and 1089 (see the figure in Appendix B for section locations) are about 1.6, 0.2 and 3.1 respectively. These values are outside the recommended limits (0.7 to 1.4) and were attributed to abrupt changes of cross-section geometry because of the presence of large ponds upstream and downstream of the bridge. The problem is, however, not significant because friction losses between sections are not significant.

Output from WSPRO showed that the Q_{10}, Q_{25}, Q_{50} and Q_{100} floods maintained open-channel flows through the bridge. The diversion discharges of 610 cfs and 1820 cfs overtopped the bridge roadway and resulted in orifice flows through the bridge opening. Among the six discharges, the flow of 1820 cfs yielded the largest velocity, i.e., 7.8 ft/sec, through the bridge opening. The design flow which maximizes velocity through the bridge opening and potentially causes the most severe scour was determined to be 480 cfs by a trial-and-error method. This discharge maintained open-channel flow and yielded a velocity of 9.2 ft/sec through the bridge. The design flow is believed to be reasonable because it maintains open-channel flow through the bridge, and less than the overtopping flow of 610 cfs due to diversion of flood from Hopkinton Reservoir to Everett Reservoir.

Results of the backwater analysis including stage, total discharge at the bridge site, amount of discharge and average velocity through the bridge opening for each flood event are presented in Table II. Water surface profiles, as well as energy grade lines for the stream reach in the vicinity of the bridge, are presented in Figure V and VI for the design flow. Results for the 10, 25, 50, 100 - year frequency floods and the two discharges (610 cfs and 1820 cfs) are presented in Figures VII to XII.

Table II

Results of Backwater Analysis

Exceedence Probability	Total Discharge At Site (cfs)	Bridge Opening			Flow Overtopping Bridge
		Discharge (cfs)	Stage	Avg. Velocity (ft/sec)	
0.1	159	159	361.3	3.2	NO
0.04	209	209	361.5	4.0	NO
0.02	241	241	361.6	4.6	NO
0.01	283	283	361.7	5.3	NO
*	610	435	363.3	6.7	YES
*	1820	508	363.3	7.8	YES
Design Flow	480	480	361.5	9.2	NO

4.2 Scour Potential Predicted with FHWA Methodology

Scour at bridge structures is comprised of three components:

(1) Aggradation and degradation: These are long-term streambed elevation changes due to natural or man-induced causes, such as movement of a bend or construction

Figure V Water Surface Elevations at Computational Cross-Sections for the Design Flow of 480 cfs

(a) Cross-Section Station 1000 ft

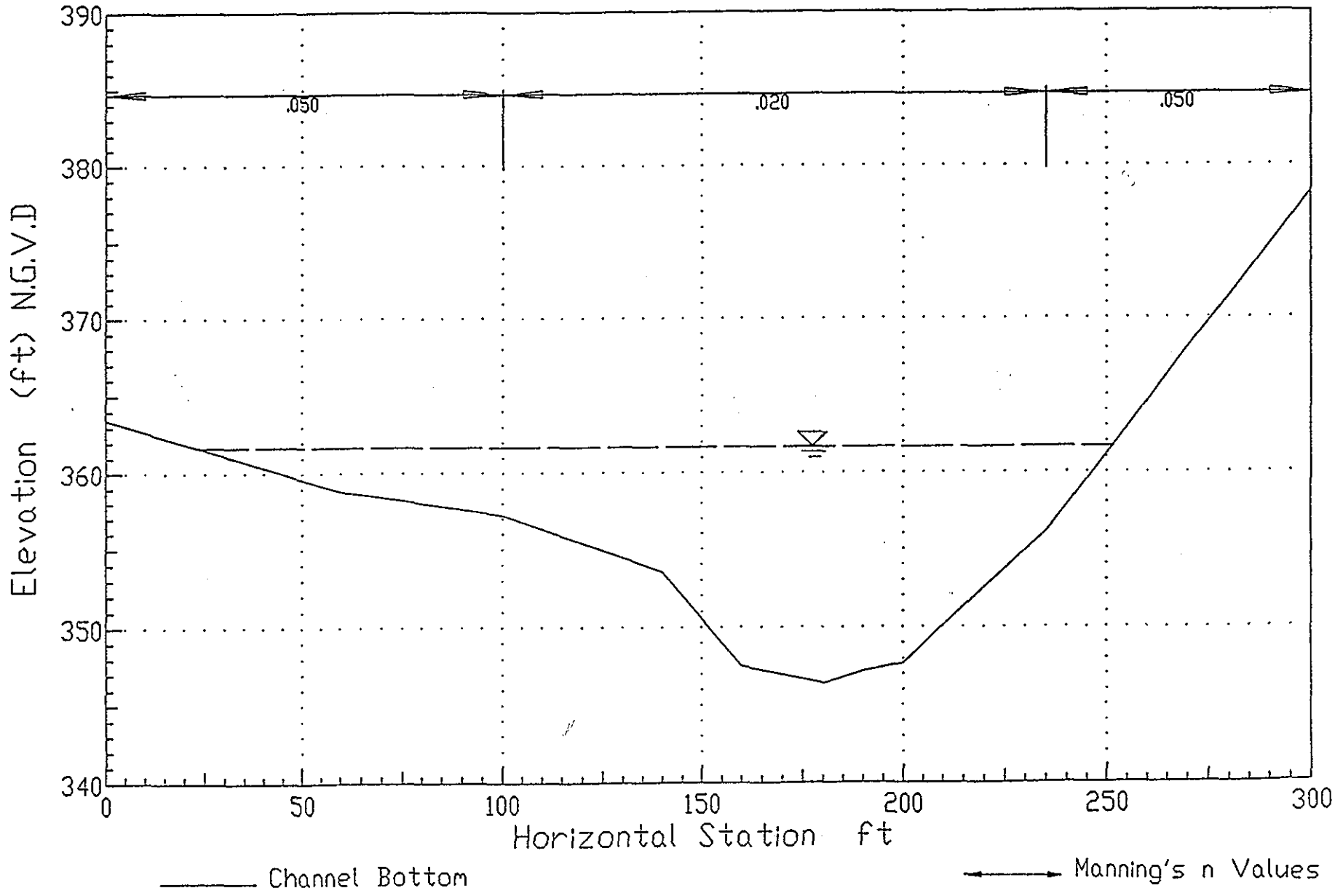


Figure V (Continued)

(b) Cross-Section Station 1030 ft

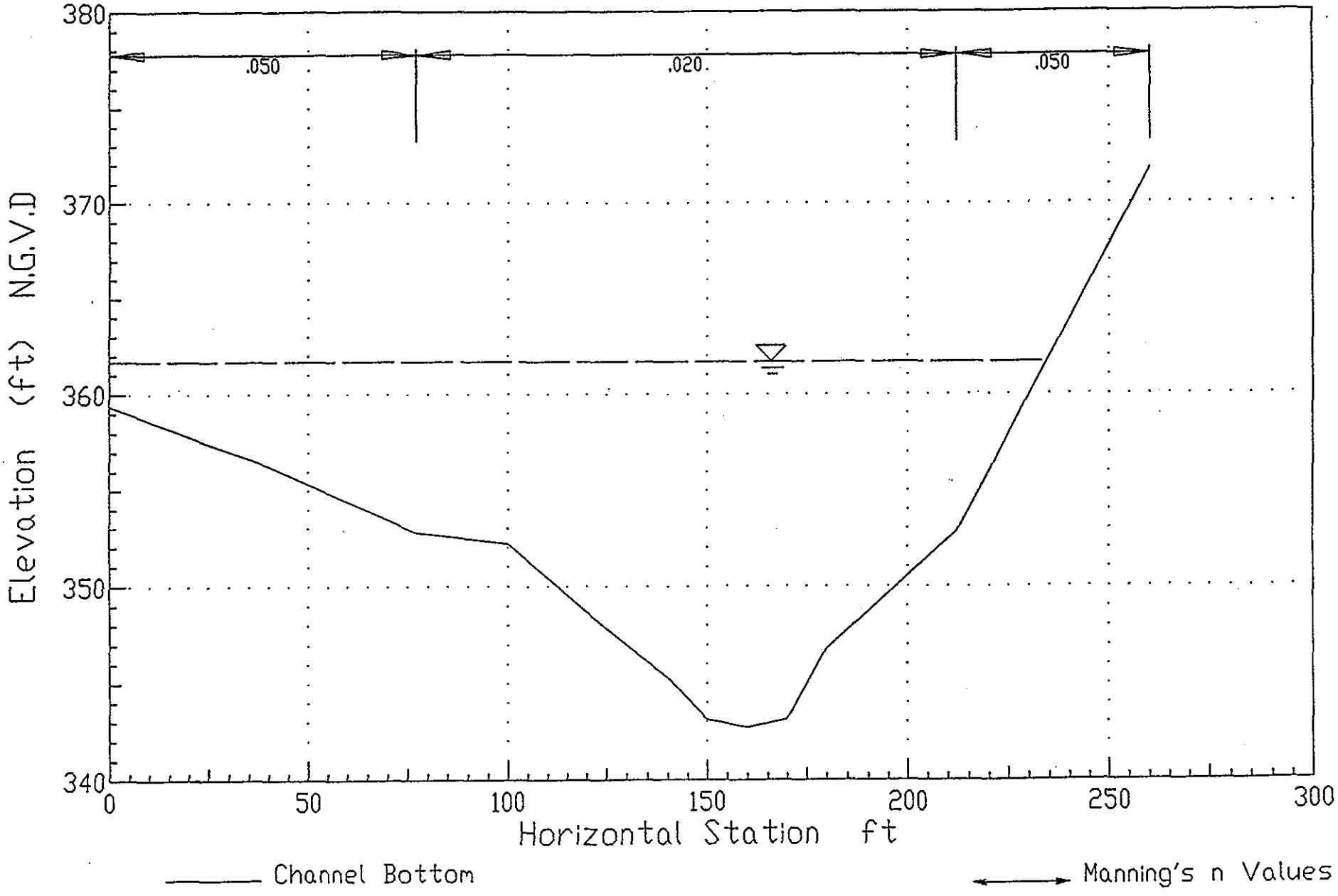


Figure V (Continued)

(c) Cross-Section Station 1060 ft

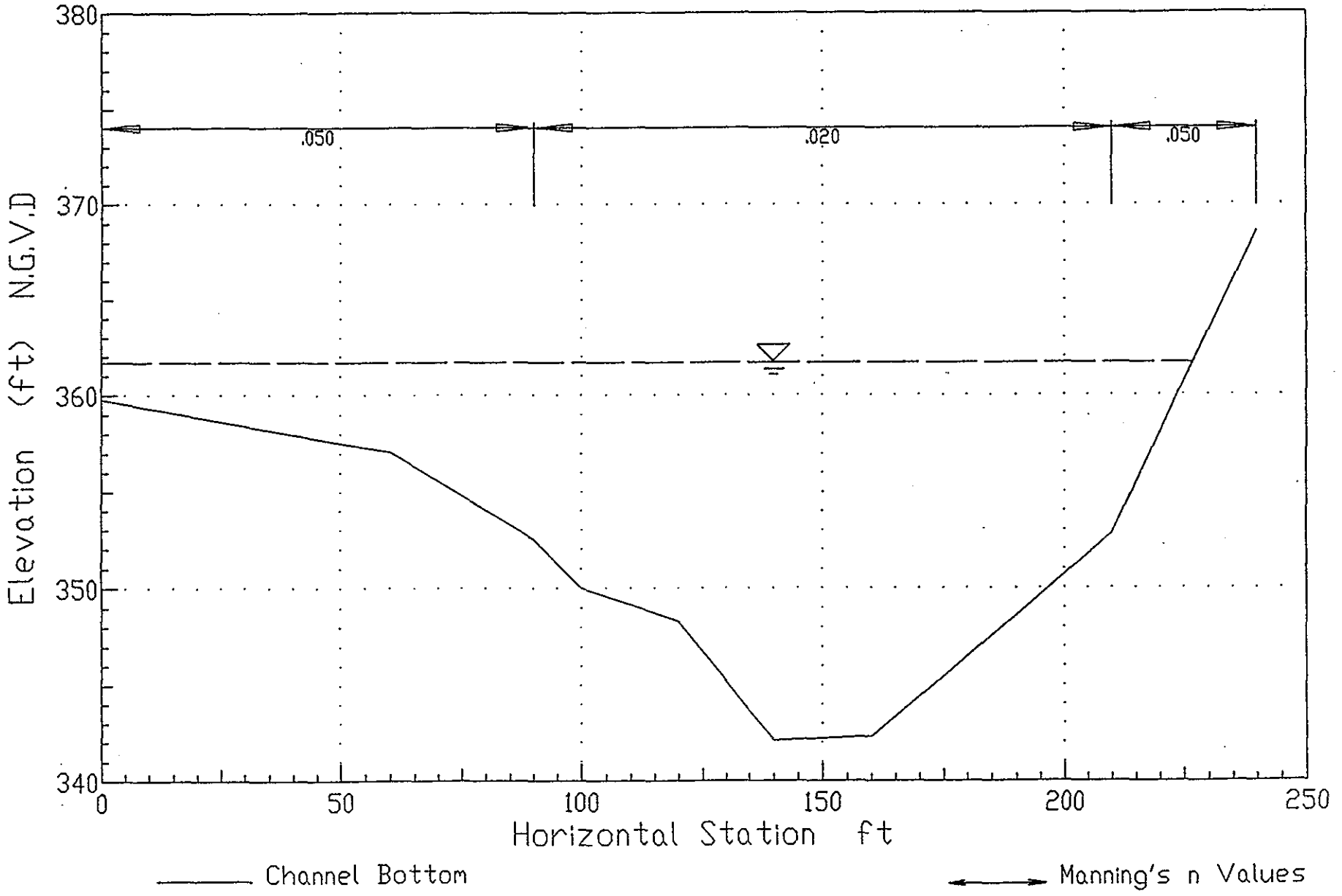


Figure V (Continued)

(d) Cross-Section Station 1080 ft

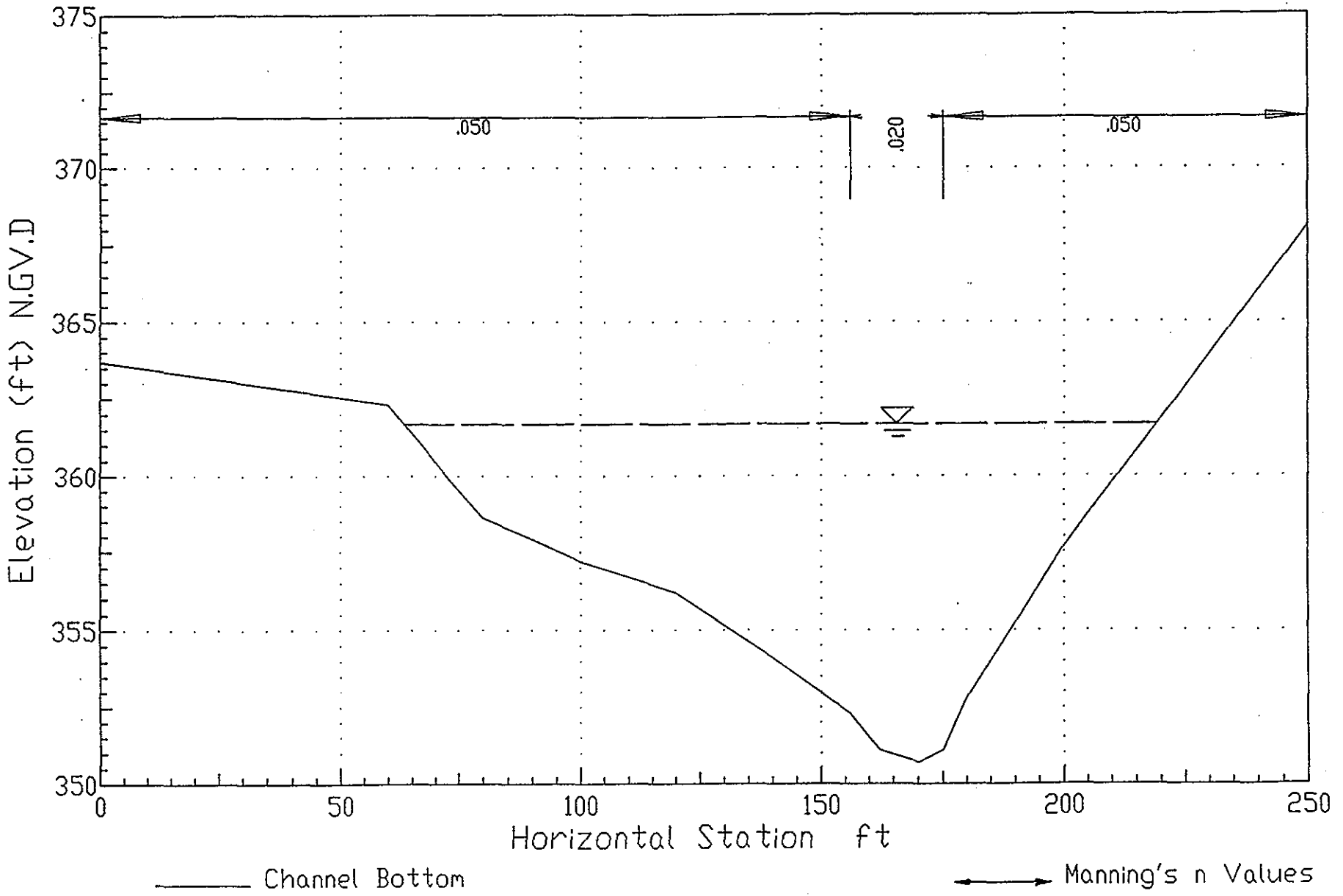


Figure V (Continued)

(e) Cross-Section Station 1089 ft

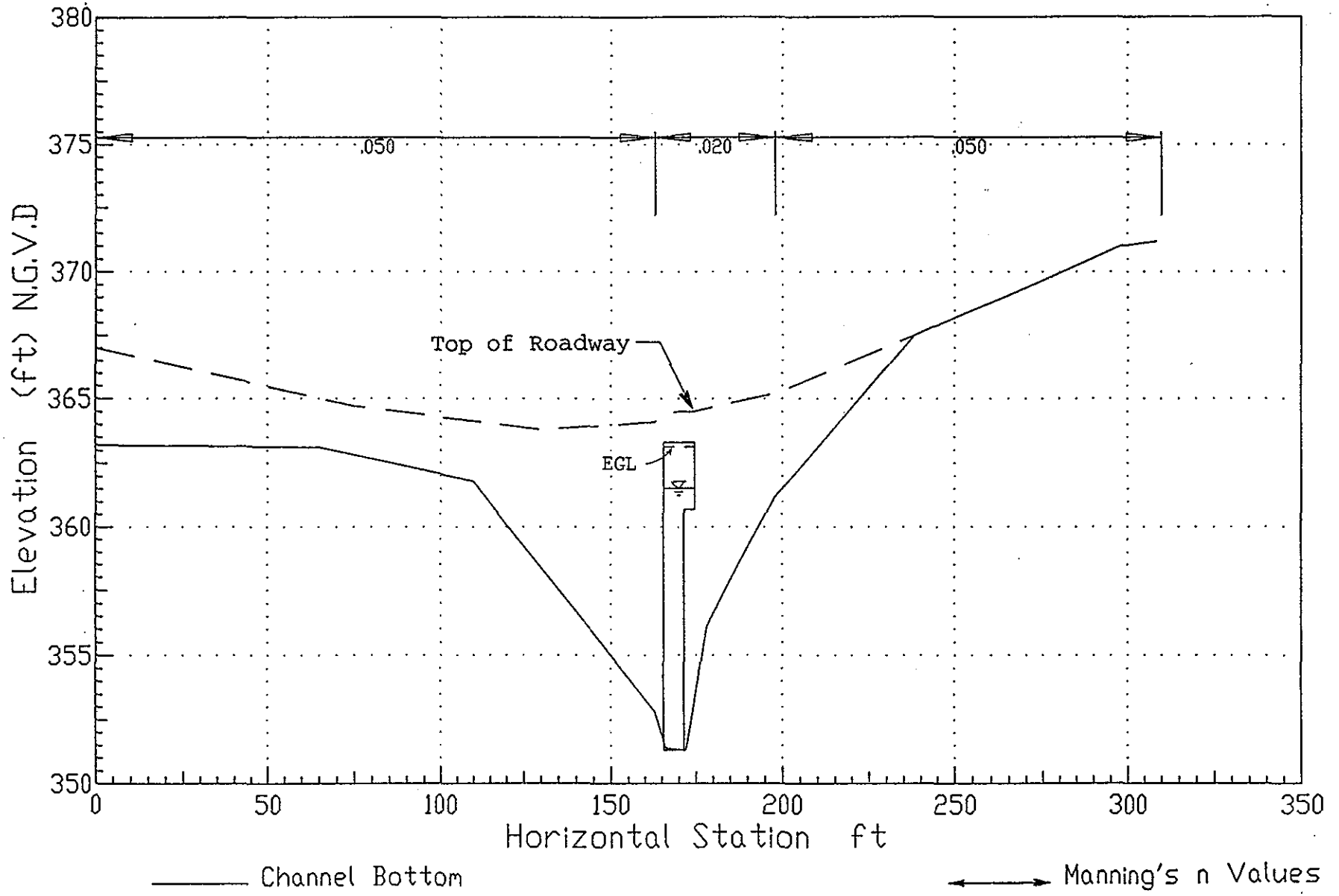


Figure V (Continued)

(f) Cross-Section Station 1125 ft

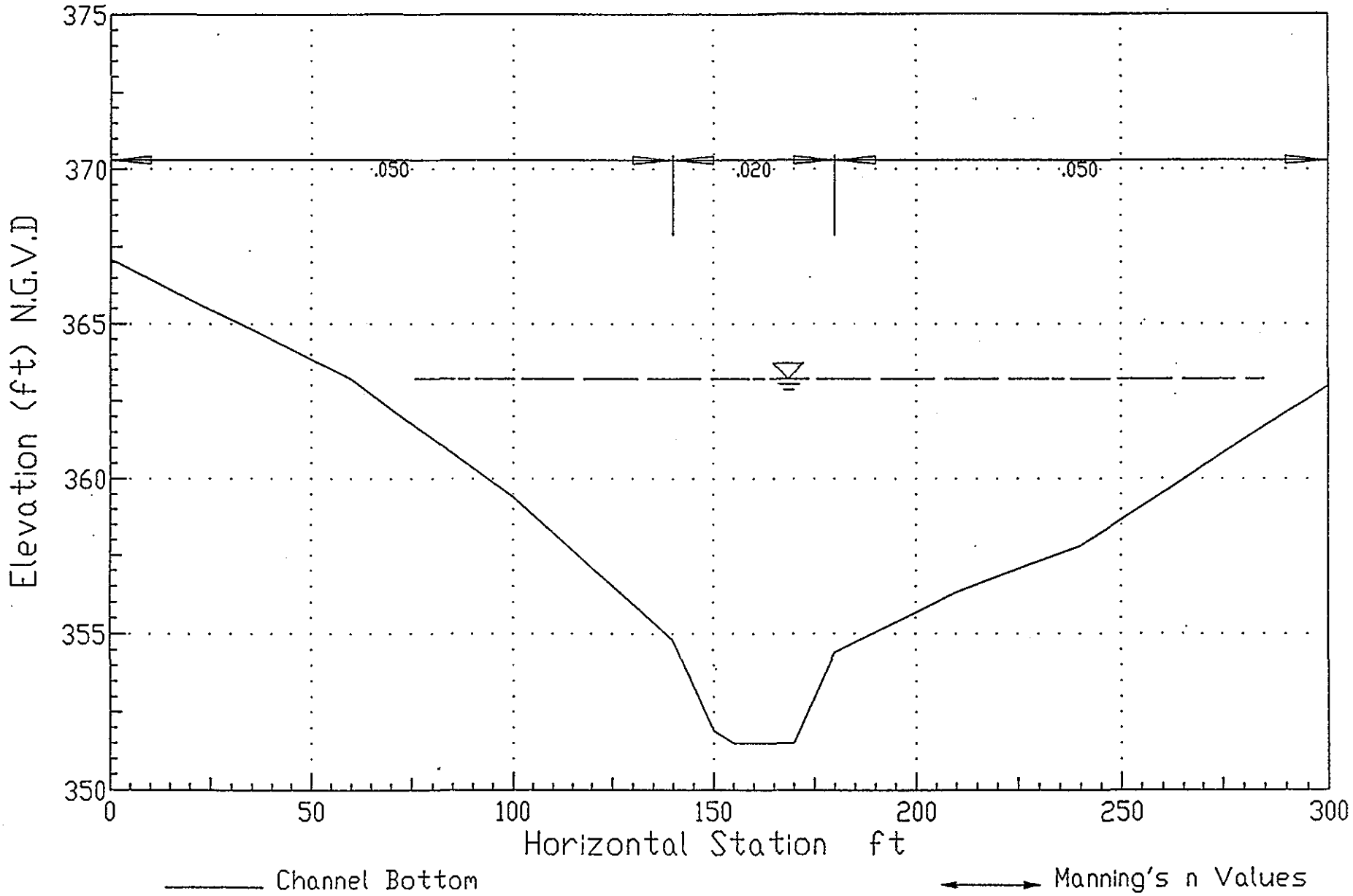


Figure V (Continued)

(g) Cross-Section Station 1154 ft

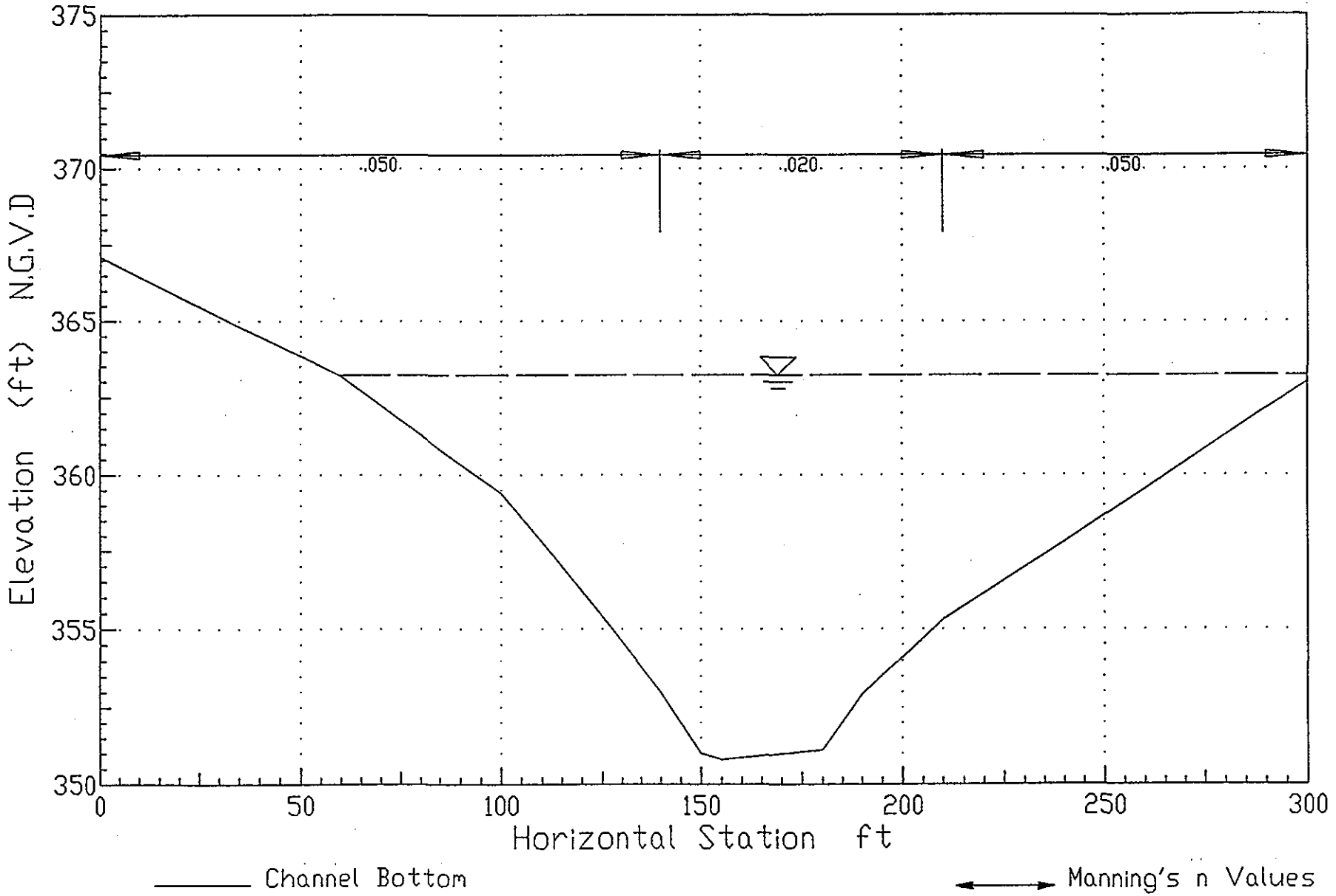


Figure VI Water Surface Profile and Energy Grade Line for the Design Flow of 480 cfs

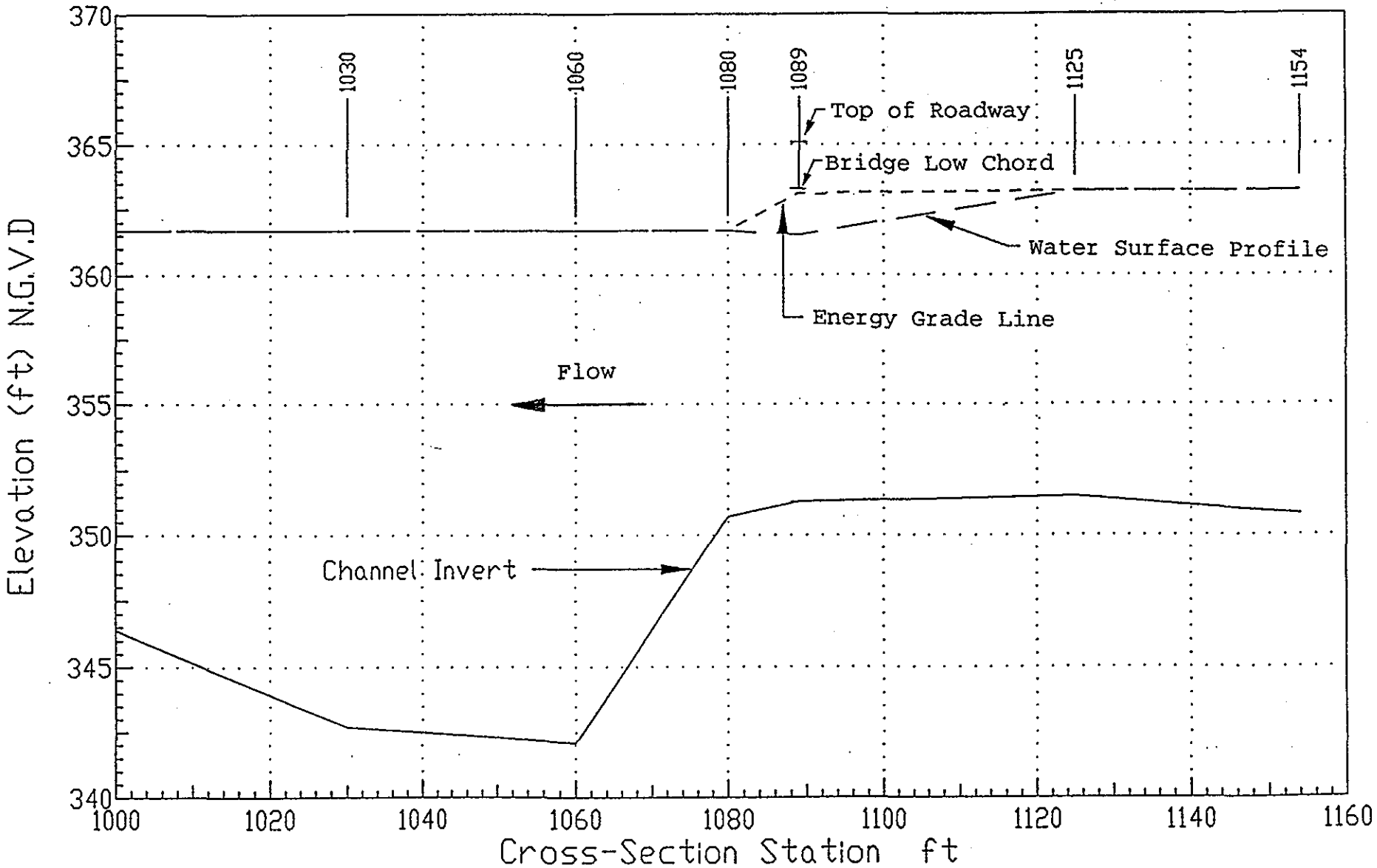


Figure VII Water Surface Profile and Energy Grade Line for Q_{10} = 159 cfs

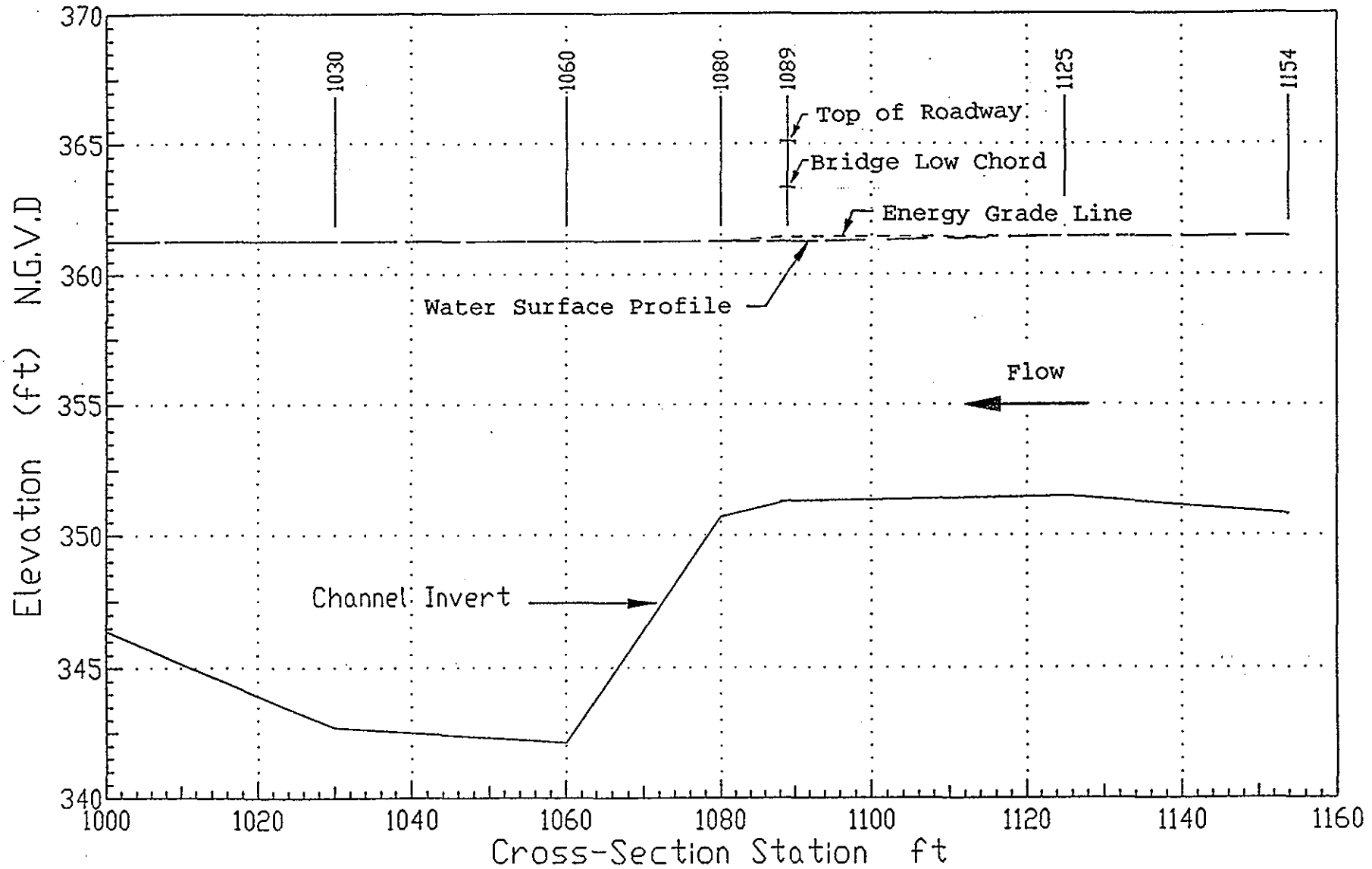


Figure VIII Water Surface Profile and Energy Grade Line for Q_{25} = 209 cfs

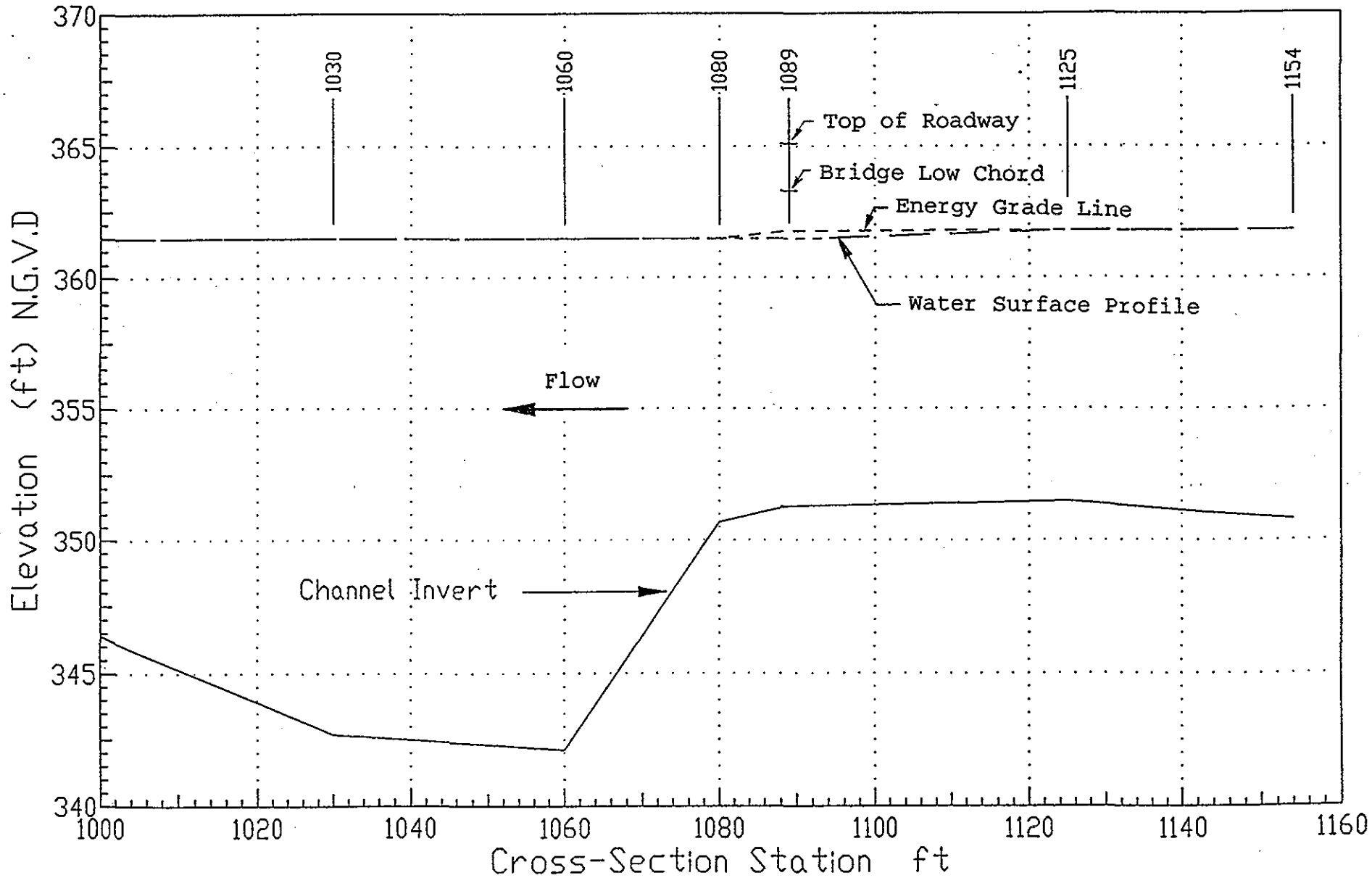


Figure IX Water Surface Profile and Energy Grade Line for Q_{50} = 241 cfs

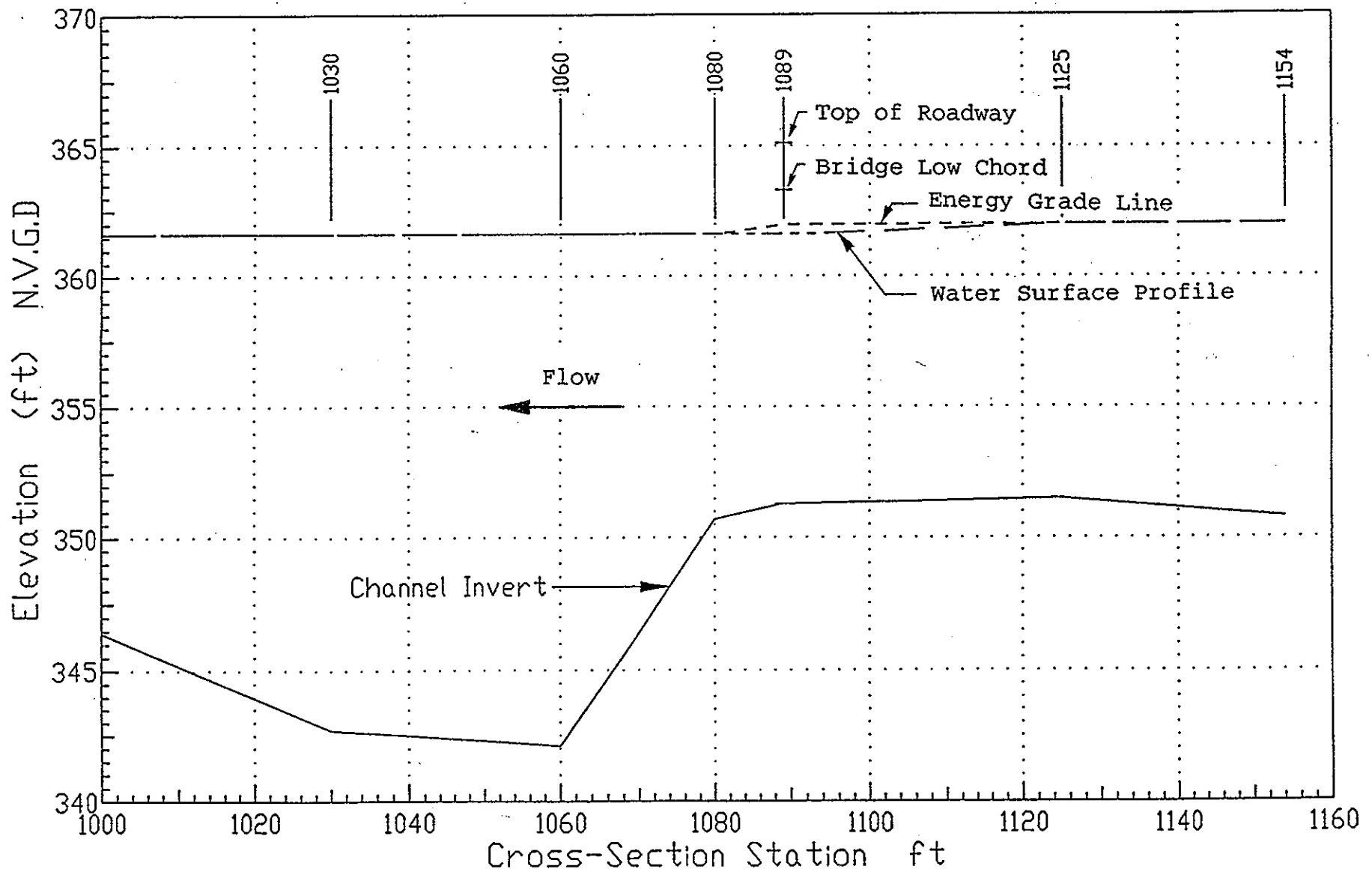


Figure X Water Surface Profile and Energy Grade Line for Q_{100} = 283 cfs

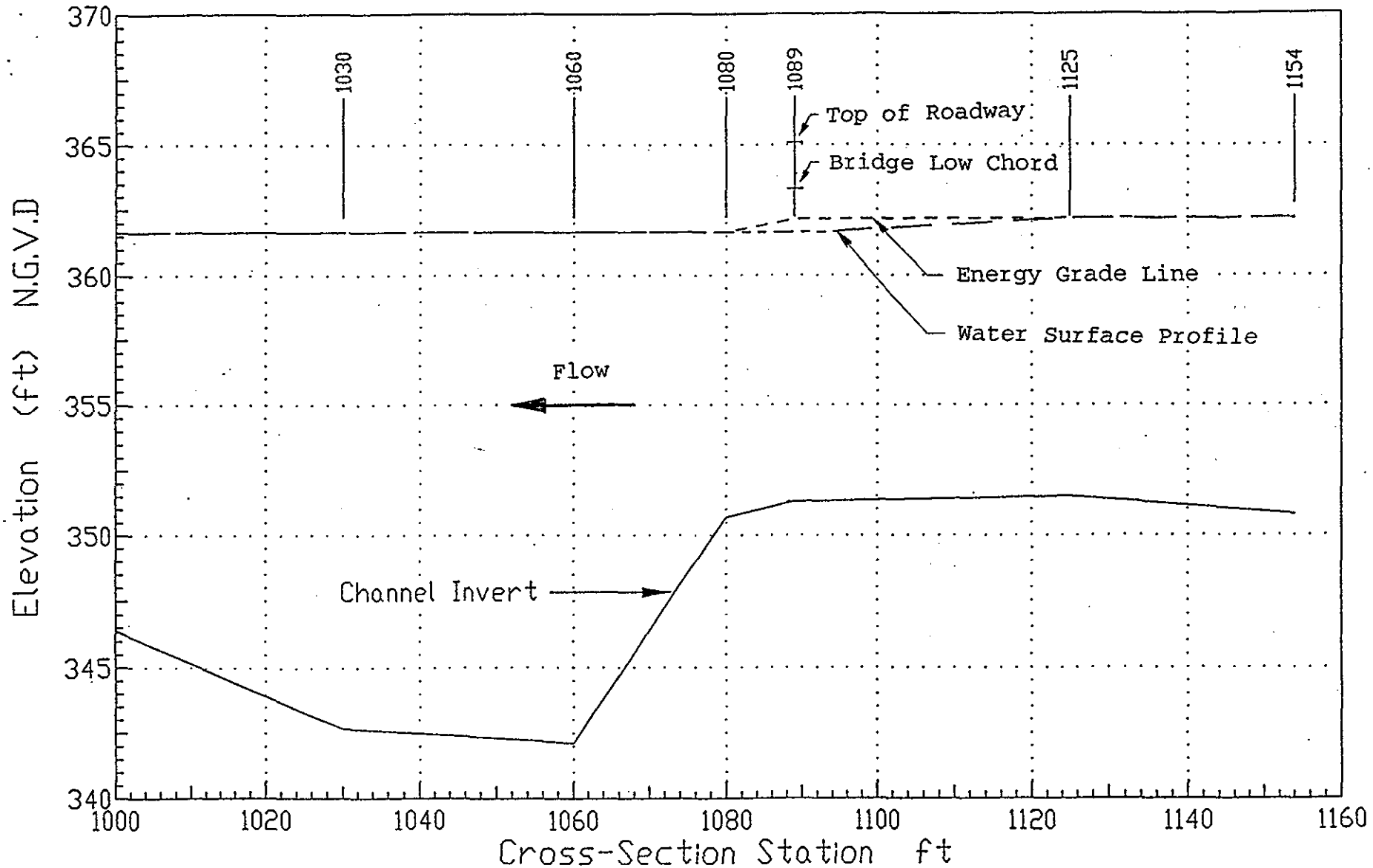


Figure XI Water Surface Profile and Energy Grade Line for Q = 610 cfs

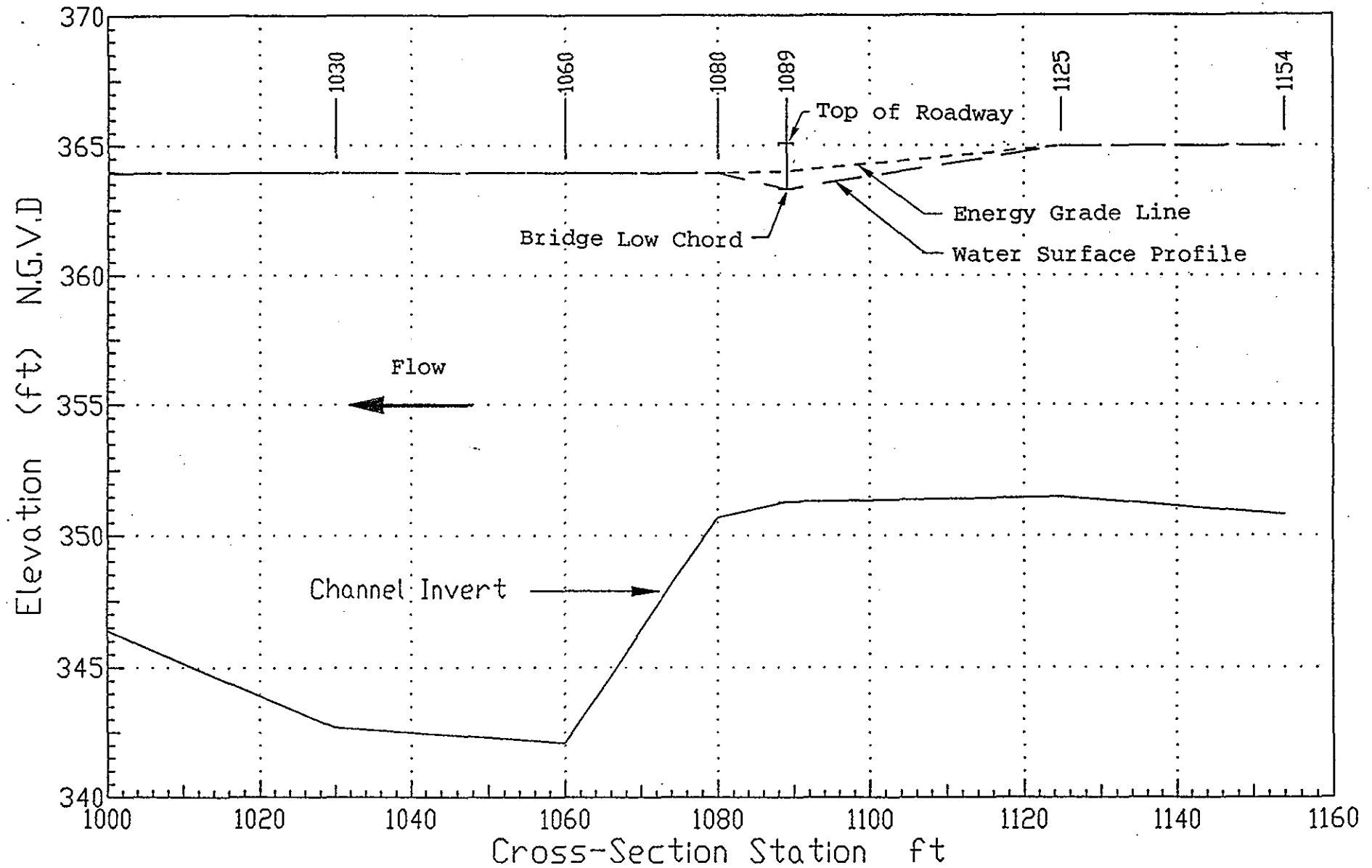
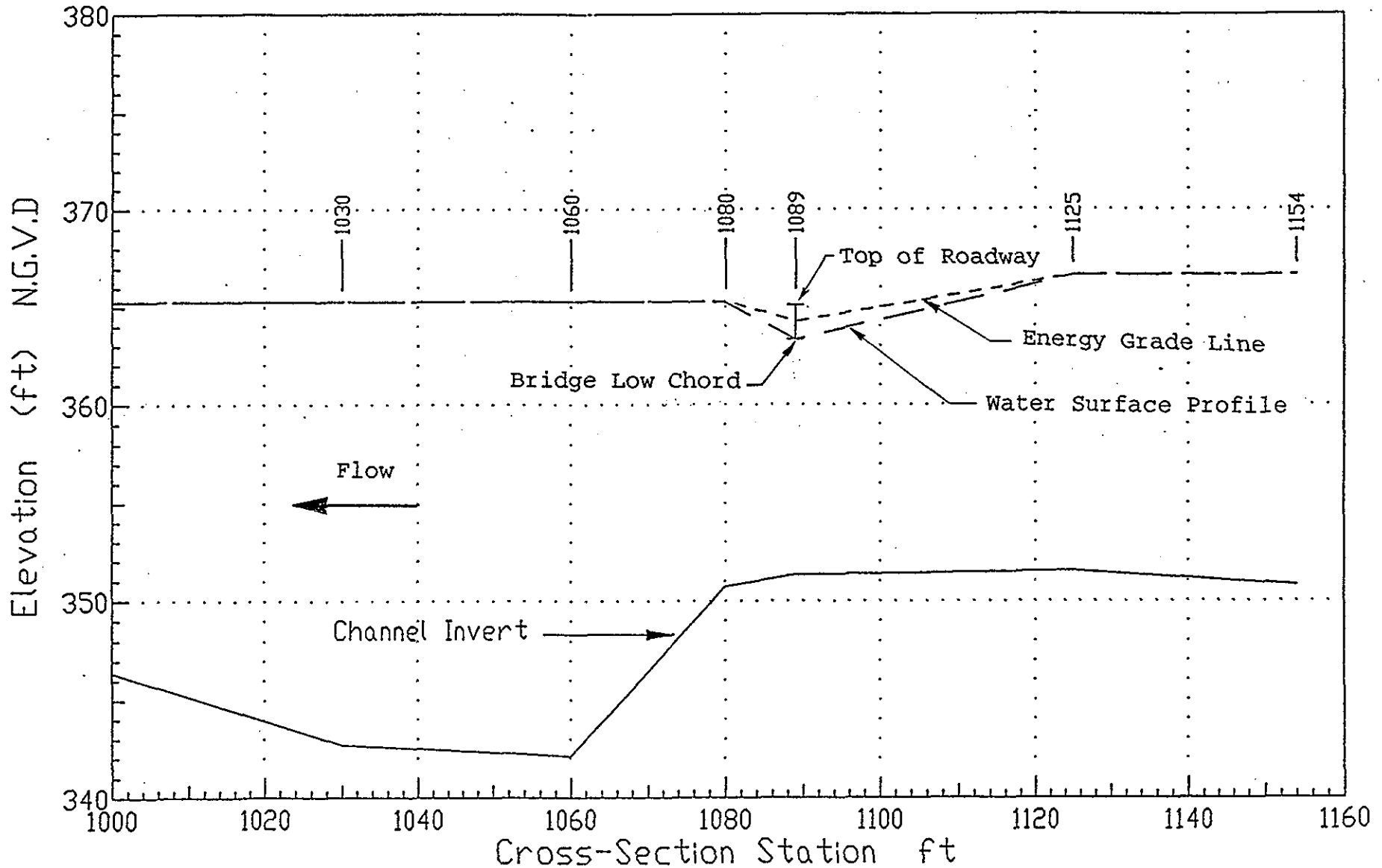


Figure XII Water Surface Profile and Energy Grade Line for Q = 1820 cfs



of a dam, in the river reach. These types of changes may occur with or without the presence of bridge structures.

(2) Contraction Scour: Contraction scour occurs as a result of decrease in channel conveyance caused by the intrusion of bridge abutments or piers into the flow.

(3) Local Scour: Local scour involves removal of sediment around abutments or piers by the accelerated flow and vortices caused by obstruction of the structures to the flow.

In analyzing scour potential at a bridge crossing, these three components must be considered. For the present study, the analyses were carried out following the guidance provided in the manual, "Evaluating Scour at Bridges" (FHWA-IP-90-017). The design flow for the analyses was 480 cfs. This flow resulted in the maximum average velocity of 9.20 ft/s at the bridge opening.

4.2.1 Aggradation and Degradation

Choate Brook passes through a marshy area. Brush on the flood plains is very dense. There are scattered trees along the banks. Site inspection showed that bed material of the stream is mainly composed of sand and gravel. Cobbles and boulders scatter over the streambed. The geotechnical investigation performed by the Corps of Engineers (Geotechnical Assessment, Sept. 1993) shows that the bed material (sand and gravel matrix) at the bridge consists of about 36.2% gravel, 61.1% sand and 2.7% silt. Sand and gravel ranges in size from below 0.08 millimeters (mm) to 52 mm. The D_{50} of the poorly graded sand with gravel is 1.5 mm. The report characterizes the sand and gravel

matrix of the streambank as essentially the same as the streambed except that there are fewer cobbles and boulders in the streambank. Considering the design flow's low velocity of less than 1.0 ft/sec at approach section upstream from the bridge and considerable amount of large-sized streambed surface material, the stream appears to be stable. No significant changes in streambed elevation would be expected and net scour due to aggradation and degradation is considered negligible.

4.2.2 Contraction Scour

The channel of Choate Brook in the vicinity of the bridge is not well defined. There are deep ponds both upstream and downstream of the bridge (see the figure in Appendix B and Figure VI). The bridge thus forms a severe restriction to the flow through it. The cause for the formation of the two ponds is not clear. Contraction of the bridge could be a factor but there is no data available for verification.

For the current situation, scour estimate using the equations available for bridge scour calculations is expected to encounter some difficulties. Nevertheless, as commented by FHWA (FHWA-IP-90-017), those equations are the ones available and should be used. At the discharge of 480 cfs, overbank flow in the upstream of Choate Brook Bridge was forced back to the channel through the bridge opening as predicted by WSPRO. Under this condition, the following Laursen's equation for live-bed scour is frequently used and recommended by FHWA (FHWA-IP-90-017) for calculating contraction scour.

$$\frac{y_2}{y_1} = \left(\frac{Q_{mc2}}{Q_{mc1}}\right)^{\frac{6}{7}} \left(\frac{W_{c1}}{W_{c2}}\right)^{k1} \left(\frac{n2}{n1}\right)^{k2} \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

The scour depth is given as

$$y_{cs} = y_2 - y_1 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

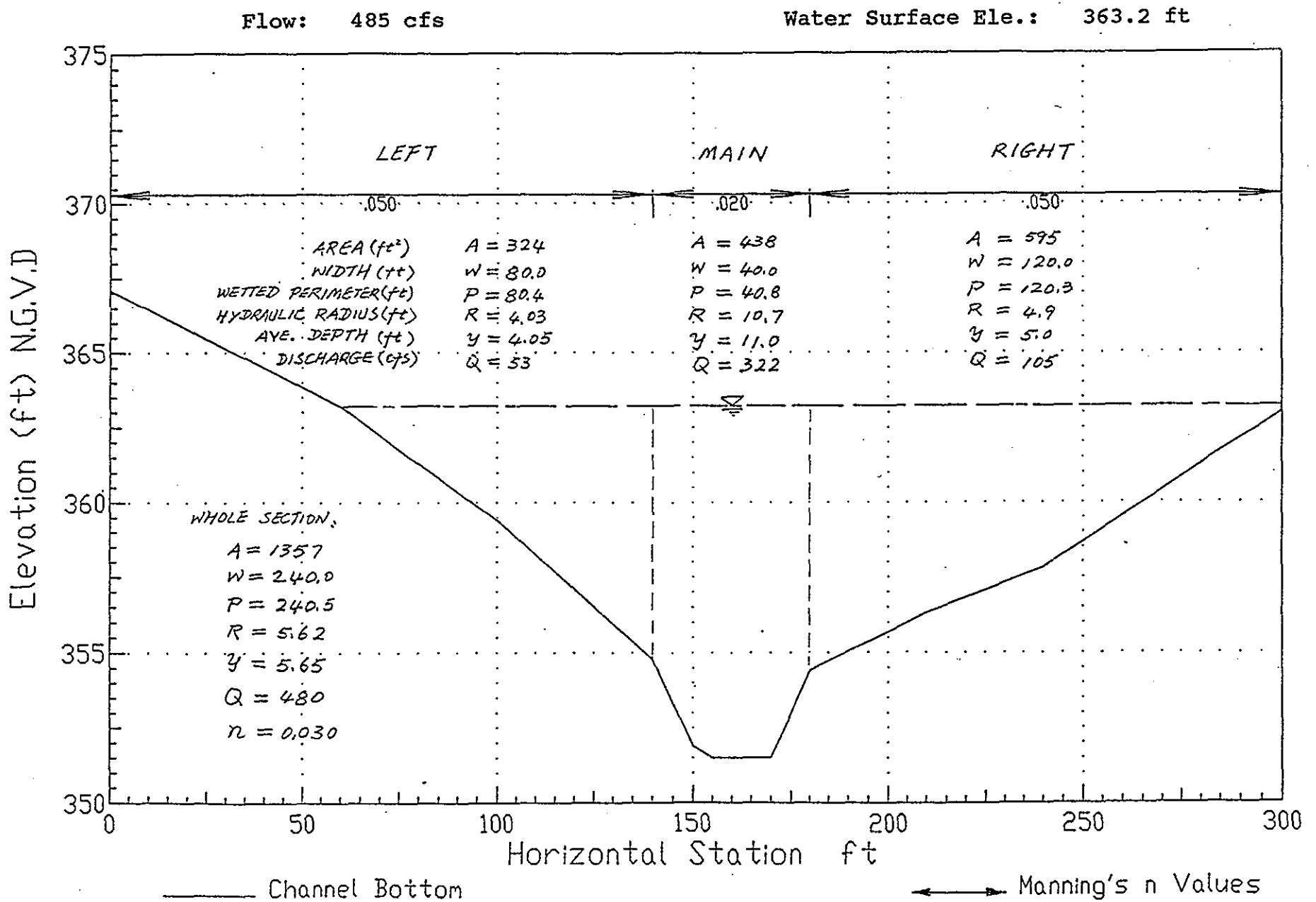
Notations and detailed calculations are presented in Appendix C. Parameters for the approach cross-section used in the calculations are also presented in Figure XIII. The scour depth calculated from Eqs. 1 and 2 was

y_{cs} = 36.3 ft.

4.2.3 Local Scour

Choate Brook Bridge has grouted stone protection around the upstream ends of the abutments. Under such circumstances, according to the recommendation by FHWA (FHWA-IP-90-017), there is no need to calculate local scour. As reported by the Corps of Engineers (Geotechnical Assessment, September 1993), several small repairs were recently made to the footings, revetments and abutments. However, the soil around and under the footing of the right abutment near the downstream corner (south end of west abutment) was found to be experiencing scour (seen partially in Photo 6). The size of the scour hole was estimated by the Corps of Engineers to be about 5 ft wide and 2 ft deep.

Figure XIII Parameters Used for Scour Computations



4.3 Critique on Scour Analyses

The scour analyses using the FHWA methodology resulted in a total scour depth of 36.3 ft. Site observation and experience indicate that this computed scour depth does not seem realistic and is believed to be overestimated. This type of problem is frequently encountered in engineering calculations due to application of empirical equations which require selection of various parameters. The uncertainty in such a procedure is expected.

The local scour equations for calculating scour at bridges were developed based primarily on laboratory data or on the basis of inductive reasoning from sediment continuity equation. Only very limited field data have been used to calibrate these equations. The equations do not account for factors such as armoring, sediment gradation, flow velocity retardation and soil retention by vegetation. Application of these equations to natural streams usually results in excessive scour depth.

A desirable approach for evaluating scour potential for the present case would be the use of a sediment transport model, for example, BRI-STARS, as suggested by FHWA (FHWA-IP-90-017). However, such an exercise is beyond the scope of the present assignment. Nevertheless, an approximate evaluation of the scour potential will be performed which may assist in the determination of whether there is a need for providing scour countermeasures to the stream reach at the bridge.

As described in Section 4.2.1., the stream passing under Choate Brook Bridge has considerable amount of coarse gravel, cobbles and boulders on the bed surface. This bed surface layer of large size material provides protection to underlying sand and fine gravel against scour. At the design flow velocity of 9.2 ft/sec through the bridge opening, the size of material which can withstand scour is estimated to be 0.54 ft. This calculation is based on the equation for evaluating degradation limited by armoring (Pemberton and Lara),

$$D = 0.00637\ V^2 \ldots\ldots (3)$$

where D = size of material in feet, and V = flow velocity in feet per second. The coefficient in Eq. 3 is an averaged value of those in Yang's equation and the equation of competent bottom velocity method, both being empirical equations. Since the bed surface layer material of Choate Brook has an average size of 0.25 - 0.50 ft which is less than the size of 0.54 ft required for withstanding scour, scour of the streambed is expected. From Eq. 3 and the continuity equation for flow, using D = 0.35 ft, the scour depth is calculated to be 2.5 ft. This scour depth appears to be more realistic. It should be pointed out, however, that this predicted scour depth be taken as a magnitude of scour potential rather than an absolute value because of the uncertainty in using empirical equations.

5.0 RECOMMENDATIONS

The analyses based on FHWA scour methodology yielded a scour depth of about 36 feet at Choate Brook Bridge. This estimation does not seem realistic as it is too large. The major problem is that the equations used for the scour analyses do not consider factors such as armoring, gradation and vegetation which have significant impact on scour development for the present case. Considering the presence of a bed surface layer of large-sized material in the stream, potential scour was estimated to be between 2 to 3 feet.

Scour protection at the bridge appears to be necessary. As a minimum, the scour hole under the right abutment footing needs to be filled. A possible method is to place concrete forms around the footing and pump concrete into the scour hole as suggested by the Corps of Engineers' Geotechnical Assessment. Protection of the streambed may not be so urgent. Field observation of scour development after a relatively large flood would help to determine whether immediate action is needed. If such an action is needed, the streambed in the vicinity of the bridge should be protected with stone rip-rap, and the design guideline provided in the manual EM 1110-2-1601 should be followed.

Beavers have accumulated debris at the upstream section of the bridge opening. The beaver dam could raise the upstream water level and, at high flow, could cause erosion

of the embankment material. As suggested in the Corps of Engineers' Geotechnical Assessment, the beaver dam should be removed.

Regarding the deep pond downstream of the bridge, it is not clear yet whether it was caused by bridge contraction. The formation of the pond does not appear to be a recent event. The deep area of the pond is about 30 feet downstream from the bridge, and there is no indication that the pond is deepening or expanding due to scour. Therefore, it does not seem necessary to install scour countermeasures to the streambed in the pond.

REFERENCES

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2. Proceedings of the Bridge Scour Symposium, U.S. Department of Transportation, Federal Highway Administration and Department of the Interior, U.S. Geological Survey, October 17-19, 1989.

3. BOSS WSPRO User's Manual, BOSS Corporation, 1991.

4. In Depth Inspection and Evaluation, Choate Brook (Old Route 77), Everett Lake, Weare, New Hampshire, U.S. Army Corps of Engineers, March, 1985.

5. "Guide for Selecting Mannings Roughness Coefficients for Natural Channels and Flood Plains", U.S. Geological Survey, Water-Supply Paper 2339, 1989.

6. EM 1110-2-1601: "Hydraulic Design of Flood Control Channels," U.S. Army Corps of Engineers, Washington, D.C., July, 1991.

7. "Bridge Waterway Analysis: Research Report", FHWA/RD-86/108, U.S. Department of Transportation, Federal Highway Administration, July 1986.

8. "Bridge Inspection Program", FY-91 Routine Inspections, U.S. Army Corps of Engineers, New England Division, November, 1991.

9. "Progress Report on Hydrologic Investigations of Small Drainage Area's in New Hampshire - Preliminary Relations for Estimating Peak Discharges on Rural, Unregulated Streams", U.S.G.S. Water-Resources Investigations 78-47, 1978.

10. US Army Corps of Engineers, "Geotechnical Assessment for Bridge Scour Study At Choate Brook Bridge", Everett Reservoir, Weare, New Hampshire, September, 1993.

11. E.L. Pemberton, and J.M. Lara, "Computing Degradation and Local Scour", Technical Guideline for Bureau of Reclamation, Denver, Colorado, January, 1984.

12. "Scope of Work for Bridge Scour Analysis at Everett Lake, Weare, New Hampshire", U.S. Army Corps of Engineers, New England Division, April 15, 1993.

APPENDIX A

Hydrologic Computations

Client CORP OF ENGINEERS - NED
Project CHOATE BROOK - SCOUR ANALYSIS
RIVER ROAD BRIDGE

Project Number Jc-151-11
Sheet ____ of ____
Date 9/16/93
Computed by C.A.A
Checked by ____

Drainage Area for the Watershed up to North Weir.

1 Square in the quadrangle sheet represents $0.386 mile^2$

# of Squares in the delineated Watershed = 17½ Squares

$(17\frac{1}{2} \times 0.386)\ mi^2$

∴ Total Drainage Area = $6.59 mi^2$

Storage Area

= 1 Square (approx.) $\times 0.386 mi^2$

= $0.386 mi^2$

$\frac{0.386}{6.59} \times \frac{100}{1} = 5.86\%$

∴ Storage Index (St)

= 5.86 + 0.5

= 6.36.

Client CORP OF ENGINEERS - NED
Project CHOATE BROOK - SCOUR ANALYSIS
RIVER ROAD BRIDGE

Project Number FE-151-11
Sheet ____ of ____
Date 9/16/93
Computed by C.A.A
Checked by ____

Slope

$$= \frac{(410-370)\,ft}{\frac{30.7}{60.5} \times 1000m \times \frac{3.28ft}{m} \times \frac{1\,mi}{5280ft}}$$

$\therefore$ Slope = 13.6 ft/mi

Applying the Regional Multiple Regression Equations for ungaged Rural Streams,

$$Q_{10} = 0.84 A^{1.06} S^{0.46} I^{1.98}$$

$$= (0.84)(6.6)^{1.06} \times (13.6)^{0.46} \times (2.8)^{1.98}$$

$$= 158.32 \text{ cfs}$$

I = Maximum 24-Hr. Precipitation having a recurrence interval of 2-years (in inches)

I for the region in question = 2.8

Client CORP OF ENGINEER - NED
Project CHDATE BROOK - SCOUR ANALYSIS
RIVER ROAD BRIDGE

Project Number 96-151-11
Sheet ____ of ____
Date 9/16
Computed by C.A.A
Checked by ____

$$Q_{25} = 0.70 A^{1.05} S^{0.52} I^{2.29}$$

$$(0.70)(6.6)^{1.05} \times (13.6)^{0.52} \times (2.8)^{2.29}$$

$$= \underline{208.45 \text{ cfs}}$$

$$Q_{50} = 0.62 A^{1.05} S^{0.54} I^{2.50}$$

$$= (0.62)(6.6)^{1.05} \times (13.6)^{0.54} \times (2.8)^{2.50}$$

$$= \underline{241.15 \text{ cfs}}$$

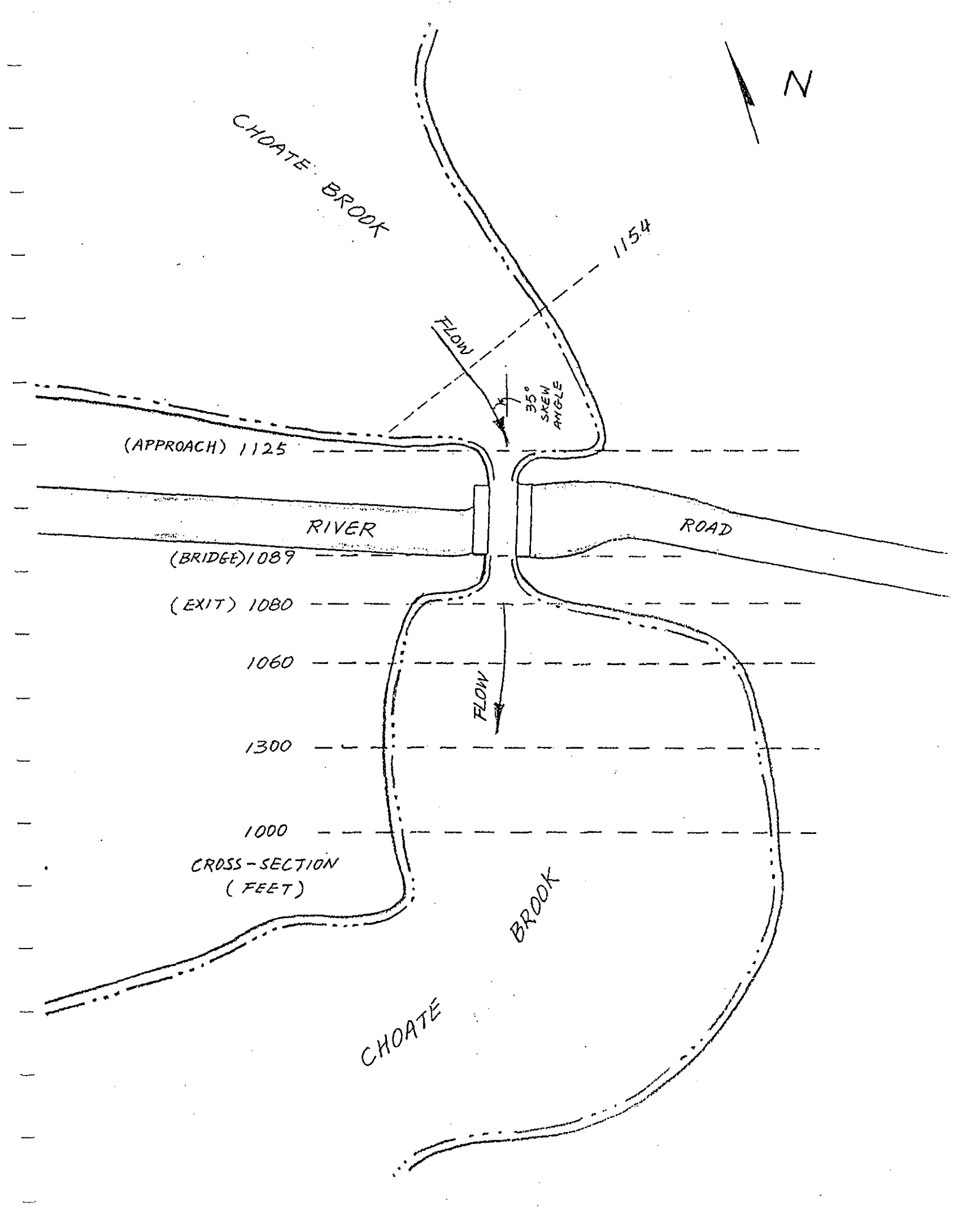
$$Q_{100} = 0.55 A^{1.05} S^{0.56} I^{2.72}$$

$$= (0.55)(6.6)^{1.05} \times (13.6)^{0.56} \times (2.8)^{2.72}$$

$$= \underline{282.69 \text{ cfs}}$$

APPENDIX B

Hydraulic Computations


N
CHOATE BROOK
1154
FLOW
35° SKEW ANGLE
(APPROACH) 1125
RIVER
ROAD
(BRIDGE) 1089
(EXIT) 1080
1060
FLOW
1300
1000
CROSS-SECTION (FEET)
BROOK
CHOATE

B O S S W S P R O (tm)

Version : 2.00
Serial Number : 0020200.200

Licensed to Hydraulic and Water Resources Engineers

PROGRAM ORIGIN :

Boss Wspro (tm) is an enhanced version of James O. Shearman's June 1988 Federal Highway Administration - U. S. Geological Survey WSPRO program for water surface profile computations.

DISCLAIMER :

Boss Wspro (tm) is a complex program which requires engineering expertise to use correctly. Boss Corporation assumes absolutely no responsibility for the correct use of this program. All results obtained should be carefully examined by an experienced professional engineer to determine if they are reasonable and accurate.

Although Boss Corporation has endeavored to make Boss Wspro error free, the program is not and cannot be certified as infallible. Therefore, Boss Corporation makes no warranty, either implicit or explicit, as to the correct performance or accuracy of this software.

In no event shall Boss Corporation be liable to anyone for special, collateral, incidental, or consequential damages in connection with or arising out of purchase or use of this software. The sole and exclusive liability to Boss Corporation, regardless of the form of action, shall not exceed the purchase price of this software.

PROJECT DESCRIPTION :

PROJECT TITLE : BRIDGE SCOUR ANALYSIS
PROJECT NUMBER : JC-151-CHOATE BRIDGE
DESCRIPTION : DIRT ROAD OVER CHOATE BROOK - NH
ENGINEER : C.A.A
DATE OF RUN : 9/20/1993
TIME OF RUN : 9:52 am

```
T1
T2
T3
*
*       10, 25, 50, AND 100 YEAR STORM EVENTS
*
J1              0.1      0.02      0.02         *         0

JOB PARAMETERS :
----------------

   Elevation Stepping Increment (DELTAY, ft)                        .1000
   Allowable Elevation Tolerance (YTOL, ft)                         .0200
   Allowable Discharge Tolerance (QTOL, %)                          .0200
   Froude Test Value (FNTEST)                                       .8000
   Computation Method                        GEOMETRIC MEAN OF CONVEYANCES

*
Q             159.0     209.0     241.0     283.0     480.0     610.0    1820.0
WS           361.27    361.48    361.62    361.73    361.68    363.93    365.27
*
*
T3        MOST DOWNSTREAM SECTION

PROCESSING CROSS-SECTION 00001 : MOST DOWNSTREAM SECTION
--------------------------------

   INPUT CARD FILE :
   -----------------

XS   00001    1000.0         *       0.30       0.10        0.0
GR              0.0     363.5       60.0      358.8      100.0      357.2
GR            140.0     353.5      160.0      347.5      180.0      346.4
GR            190.0     347.2      200.0      347.7      235.0      356.1
GR            300.0     378.2
N              0.05      0.02       0.05
SA            100.0     235.0
FL 0              *         *          *          *          *
*
T3        DOWNSTREAM SECTION

   DATA SUMMARY FOR CROSS-SECTION 00001 :
   --------------------------------------

   Section Reference Distance (SRD, ft)                          1000.00
   Error Code (ERR)                                                    0
   Cross-Section Skew (SKEW, degrees)                                .00
   Valley Slope or Grade (VSLOPE, ft/ft)                          .00000
   Expansion Coefficient (EK)                                        .30
   Contraction Coefficient (CK)                                      .10
   Computation Method                        GEOMETRIC MEAN OF CONVEYANCES
```

CROSS-SECTION GEOMETRY (X-Y coordinate pairs) :

Ground Station X(I) (ft)	Ground Elevation Y(I) (ft MSL)	Ground Station X(I+1) (ft)	Ground Elevation Y(I+1) (ft MSL)	Ground Station X(I+2) (ft)	Ground Elevation Y(I+2) (ft MSL)
.00	363.50	60.00	358.80	100.00	357.20
140.00	353.50	160.00	347.50	180.00	346.40
190.00	347.20	200.00	347.70	235.00	356.10
300.00	378.20				

CROSS-SECTION ROUGHNESS DESCRIPTION :

Horiz. Break-Point Station (ft)	Subarea Manning n
*********	.0500
100.00	.0200
235.00	.0500

PROCESSING CROSS-SECTION 00002 : DOWNSTREAM SECTION

INPUT CARD FILE :

```
XS   00002    1030.0        *       0.30      0.10      0.0
GR              0.0       359.4     40.0      356.3     77.0     352.8
GR              100.0     352.2     120.0     348.7     140.0    345.3
GR              150.0     343.1     160.0     342.7     170.0    343.1
GR              180.0     346.8     212.0     352.8     260.0    371.8
N               0.05      0.02      0.05
SA              77.0      212.0
FL 0              *         *         *         *         *
*
T3        DOWNSTREAM SECTION
```

DATA SUMMARY FOR CROSS-SECTION 00002 :

Section Reference Distance (SRD, ft)	1030.00
Error Code (ERR)	0
Cross-Section Skew (SKEW, degrees)	.00
Valley Slope or Grade (VSLOPE, ft/ft)	.00000
Expansion Coefficient (EK)	.30
Contraction Coefficient (CK)	.10

Computation Method GEOMETRIC MEAN OF CONVEYANCES

CROSS-SECTION GEOMETRY (X-Y coordinate pairs) :

Ground Station X(I) (ft)	Ground Elevation Y(I) (ft MSL)	Ground Station X(I+1) (ft)	Ground Elevation Y(I+1) (ft MSL)	Ground Station X(I+2) (ft)	Ground Elevation Y(I+2) (ft MSL)
.00	359.40	40.00	356.30	77.00	352.80
100.00	352.20	120.00	348.70	140.00	345.30
150.00	343.10	160.00	342.70	170.00	343.10
180.00	346.80	212.00	352.80	260.00	371.80

CROSS-SECTION ROUGHNESS DESCRIPTION :

Horiz. Break-Point Station (ft)	Subarea Manning n
*********	.0500
77.00	.0200
212.00	.0500

PROCESSING CROSS-SECTION 00003 : DOWNSTREAM SECTION

INPUT CARD FILE :

```
XS   00003    1060.0        *      0.30      0.10       0.0
GR              0.0      359.8      30.0      358.4      60.0      357.1
GR             90.0      352.5     100.0      350.0     120.0      348.3
GR            140.0      342.1     160.0      342.3     180.0      346.5
GR            210.0      352.8     240.0      368.6
N               0.05       0.02      0.05
SA             90.0      210.0
FL 0            *          *         *          *         *
*
T3        DOWNSTREAM SECTION
```

DATA SUMMARY FOR CROSS-SECTION 00003 :

Section Reference Distance (SRD, ft)	1060.00
Error Code (ERR)	0

Cross-Section Skew (SKEW, degrees)	.00
Valley Slope or Grade (VSLOPE, ft/ft)	.00000
Expansion Coefficient (EK)	.30
Contraction Coefficient (CK)	.10
Computation Method	GEOMETRIC MEAN OF CONVEYANCES

CROSS-SECTION GEOMETRY (X-Y coordinate pairs) :

Ground Station X(I) (ft)	Ground Elevation Y(I) (ft MSL)	Ground Station X(I+1) (ft)	Ground Elevation Y(I+1) (ft MSL)	Ground Station X(I+2) (ft)	Ground Elevation Y(I+2) (ft MSL)
.00	359.80	30.00	358.40	60.00	357.10
90.00	352.50	100.00	350.00	120.00	348.30
140.00	342.10	160.00	342.30	180.00	346.50
210.00	352.80	240.00	368.60		

CROSS-SECTION ROUGHNESS DESCRIPTION :

Horiz. Break-Point Station (ft)	Subarea Manning n
*********	.0500
90.00	.0200
210.00	.0500

PROCESSING CROSS-SECTION 00004 : DOWNSTREAM SECTION

INPUT CARD FILE :

```
XS   00004    1080.0        *      0.30      0.10       0.0
GR             0.0       363.7     60.0      362.3      80.0      358.6
GR             100.0     357.2     120.0     356.2      140.0     354.1
GR             156.0     352.3     162.0     351.1      170.0     350.7
GR             175.0     351.1     180.0     352.8      200.0     357.7
GR             250.0     368.1
N              0.05       0.02      0.05
SA             156.0     175.0
FL 0             *         *         *         *          *
*
T3        BRIDGE SECTION
```

DATA SUMMARY FOR CROSS-SECTION 00004 :

Section Reference Distance (SRD, ft)	1080.00
Error Code (ERR)	0
Cross-Section Skew (SKEW, degrees)	.00
Valley Slope or Grade (VSLOPE, ft/ft)	.00000
Expansion Coefficient (EK)	.30
Contraction Coefficient (CK)	.10
Computation Method	GEOMETRIC MEAN OF CONVEYANCES

CROSS-SECTION GEOMETRY (X-Y coordinate pairs) :

Ground Station X(I) (ft)	Ground Elevation Y(I) (ft MSL)	Ground Station X(I+1) (ft)	Ground Elevation Y(I+1) (ft MSL)	Ground Station X(I+2) (ft)	Ground Elevation Y(I+2) (ft MSL)
.00	363.70	60.00	362.30	80.00	358.60
100.00	357.20	120.00	356.20	140.00	354.10
156.00	352.30	162.00	351.10	170.00	350.70
175.00	351.10	180.00	352.80	200.00	357.70
250.00	368.10				

CROSS-SECTION ROUGHNESS DESCRIPTION :

Horiz. Break-Point Station (ft)	Subarea Manning n
*********	.0500
156.00	.0200
175.00	.0500

PROCESSING CROSS-SECTION 00005 : BRIDGE SECTION

INPUT CARD FILE :

```
XS   00005    1089.0        *      0.50      0.30      0.0
GR             0.0       363.2     65.0      363.1     110.0     361.8
GR             163.0     352.8     166.0     351.4     172.0     351.3
GR             174.0     352.8     178.0     356.1     198.0     361.2
GR             238.0     367.5     298.0     371.0
N              0.05      0.02      0.05
SA             163.0     198.0
FL 0              *         *         *         *         *
*
```

DATA SUMMARY FOR CROSS-SECTION 00005 :

Section Reference Distance (SRD, ft)	1089.00
Error Code (ERR)	0
Cross-Section Skew (SKEW, degrees)	.00
Valley Slope or Grade (VSLOPE, ft/ft)	.00000
Expansion Coefficient (EK)	.50
Contraction Coefficient (CK)	.30
Computation Method	GEOMETRIC MEAN OF CONVEYANCES

CROSS-SECTION GEOMETRY (X-Y coordinate pairs) :

Ground Station X(I) (ft)	Ground Elevation Y(I) (ft MSL)	Ground Station X(I+1) (ft)	Ground Elevation Y(I+1) (ft MSL)	Ground Station X(I+2) (ft)	Ground Elevation Y(I+2) (ft MSL)
.00	363.20	65.00	363.10	110.00	361.80
163.00	352.80	166.00	351.40	172.00	351.30
174.00	352.80	178.00	356.10	198.00	361.20
238.00	367.50	298.00	371.00		

CROSS-SECTION ROUGHNESS DESCRIPTION :

Horiz. Break-Point Station (ft)	Subarea Manning n
*********	.0500
163.00	.0200
198.00	.0500

PROCESSING CROSS-SECTION 00006 : BRIDGE SECTION

INPUT CARD FILE :

```
BR   00006    1089.0     363.3      35.0        *        *        *
GR             165.5     363.3     165.5     351.3    171.5    351.3
GR             171.5     360.7     174.5     360.7    174.5    363.3
GR             165.5     363.3
AB                 *         *     351.9     352.2
CD                 2     27.15       2.0     365.1        *        *        *
N              0.012
*
```

DATA SUMMARY FOR CROSS-SECTION 00006 :

Section Reference Distance (SRD, ft)	1089.00
Error Code (ERR)	0
Cross-Section Skew (SKEW, degrees)	35.00
Valley Slope or Grade (VSLOPE, ft/ft)	.00000
Expansion Coefficient (EK)	.50
Contraction Coefficient (CK)	.30
Computation Method	GEOMETRIC MEAN OF CONVEYANCES

BRIDGE OPENING GEOMETRY (X-Y coordinate pairs) :

Horiz. Station X(I) (ft)	Opening Elevation Y(I) (ft MSL)	Horiz. Station X(I+1) (ft)	Opening Elevation Y(I+1) (ft MSL)	Horiz. Station X(I+2) (ft)	Opening Elevation Y(I+2) (ft MSL)
165.50	363.30	165.50	351.30	171.50	351.30
171.50	360.70	174.50	360.70	174.50	363.30
165.50	363.30				

CROSS-SECTION ROUGHNESS DESCRIPTION :

Manning's Roughness n	.0120

BRIDGE DESCRIPTION :

Bridge Opening Type (BRTYPE)	2
Bridge Deck Width (BRWDTH, ft)	27.15
Bridge Opening Low Chord Elev (LSEL, ft MSL)	363.30
Bridge Discharge Coefficient (USERCD)	**********
Bridge Embankment Side Slope (EMBSS)	1 : 2.000
Top of Embankment Elevation (EMBELV, ft MSL)	365.10
Left Abutment Toe Elevation (YABLT, ft MSL)	351.90
Right Abutment Toe Elevation (YABRT, ft MSL)	352.20

PROCESSING CROSS-SECTION 00007 : BRIDGE SECTION

INPUT CARD FILE :

```
XR   00007    1107.6     27.15        2         *      35.0
GR              0.0      367.0      75.0     364.7     130.0     363.8
GR            163.0      364.1     166.0     364.4     170.0     364.5
GR            174.0      364.5     178.0     364.6     198.0     365.2
GR            238.0      367.5     298.0     371.0     310.0     371.2
*
T3        APPROACH SECTION
```

STATUS: No roughness data input, will propagate from previous cross-section.

DATA SUMMARY FOR CROSS-SECTION 00007 :

Section Reference Distance (SRD, ft)	1107.60
Error Code (ERR)	0
Cross-Section Skew (SKEW, degrees)	35.00
Valley Slope or Grade (VSLOPE, ft/ft)	.00000
Expansion Coefficient (EK)	.50
Contraction Coefficient (CK)	.30
Computation Method	GEOMETRIC MEAN OF CONVEYANCES

ROAD GEOMETRY (X-Y coordinate pairs) :

Horiz. Station X(I) (ft)	Opening Elevation Y(I) (ft MSL)	Horiz. Station X(I+1) (ft)	Opening Elevation Y(I+1) (ft MSL)	Horiz. Station X(I+2) (ft)	Opening Elevation Y(I+2) (ft MSL)
.00	367.00	75.00	364.70	130.00	363.80
163.00	364.10	166.00	364.40	170.00	364.50
174.00	364.50	178.00	364.60	198.00	365.20
238.00	367.50	298.00	371.00	310.00	371.20

CROSS-SECTION ROUGHNESS DESCRIPTION :

Horiz. Break-Point Station (ft)	Subarea Manning n
*********	.0500
163.00	.0200
198.00	.0500

ROAD GRADE DESCRIPTION :

Road Surface Material (IPAVE)	GRAVEL
Embankment Top Width (RDWID, m)	27.15
Weir Flow Coefficient (USERCF)	**********

PROCESSING CROSS-SECTION 00008 : APPROACH SECTION

INPUT CARD FILE :

```
AS   00008    1125.0        *      0.30      0.10      0.0
GR              0.0     367.1      60.0     363.2     100.0     359.4
GR            140.0     354.8     150.0     351.9     155.0     351.5
GR            170.0     351.5     180.0     354.4     210.0     356.3
GR            240.0     357.8     270.0     360.4     300.0     363.0
N              0.05      0.02      0.05
SA            140.0     210.0
FL 0              *         *         *         *         *
*
T3        UPSTREAM SECTION
```

DATA SUMMARY FOR CROSS-SECTION 00008 :

Section Reference Distance (SRD, ft)	1125.00
Error Code (ERR)	0
Cross-Section Skew (SKEW, degrees)	.00
Valley Slope or Grade (VSLOPE, ft/ft)	.00000
Expansion Coefficient (EK)	.30
Contraction Coefficient (CK)	.10
Computation Method	GEOMETRIC MEAN OF CONVEYANCES

CROSS-SECTION GEOMETRY (X-Y coordinate pairs) :

Ground Station X(I) (ft)	Ground Elevation Y(I) (ft MSL)	Ground Station X(I+1) (ft)	Ground Elevation Y(I+1) (ft MSL)	Ground Station X(I+2) (ft)	Ground Elevation Y(I+2) (ft MSL)
.00	367.10	60.00	363.20	100.00	359.40
140.00	354.80	150.00	351.90	155.00	351.50
170.00	351.50	180.00	354.40	210.00	356.30
240.00	357.80	270.00	360.40	300.00	363.00

CROSS-SECTION ROUGHNESS DESCRIPTION :

Horiz. Break-Point Station (ft)	Subarea Manning n
*********	.0500
140.00	.0200
210.00	.0500

PROCESSING CROSS-SECTION 00009 : UPSTREAM SECTION

INPUT CARD FILE :

```
XS   00009    1154.0        *      0.30      0.10      0.0
GR             0.0       367.1     60.0      363.2     100.0     359.4
GR             140.0     353.0     150.0     351.0     155.0     350.8
GR             180.0     351.1     190.0     352.9     210.0     355.3
GR             240.0     357.8     270.0     360.4     300.0     363.0
N              0.05      0.02      0.05
SA             140.0     210.0
FL 0             *         *         *         *         *
*
EX               0         0         0         0         0         0         0
```

DATA SUMMARY FOR CROSS-SECTION 00009 :

Section Reference Distance (SRD, ft)	1154.00
Error Code (ERR)	0
Cross-Section Skew (SKEW, degrees)	.00
Valley Slope or Grade (VSLOPE, ft/ft)	.00000
Expansion Coefficient (EK)	.30
Contraction Coefficient (CK)	.10
Computation Method	GEOMETRIC MEAN OF CONVEYANCES

CROSS-SECTION GEOMETRY (X-Y coordinate pairs) :

Ground Station X(I) (ft)	Ground Elevation Y(I) (ft MSL)	Ground Station X(I+1) (ft)	Ground Elevation Y(I+1) (ft MSL)	Ground Station X(I+2) (ft)	Ground Elevation Y(I+2) (ft MSL)
.00	367.10	60.00	363.20	100.00	359.40
140.00	353.00	150.00	351.00	155.00	350.80
180.00	351.10	190.00	352.90	210.00	355.30
240.00	357.80	270.00	360.40	300.00	363.00

CROSS-SECTION ROUGHNESS DESCRIPTION :

Horiz. Break-Point Station (ft)	Subarea Manning n
*********	.0500
140.00	.0200
210.00	.0500

BEGINNING PROFILE CALCULATIONS :

PROFILE NUMBER 1 :

Cross Section ID Code XSID	Flow Length FLEN (ft)	Flow Area AREA (sq ft)	Left Edge of Water LEW (ft)	Vel. Head Correct. Factor ALPH	Friction Loss HF (ft)	Energy Gradeline Elevation EGL (ft MSL)
Section Reference Distance SRD (ft)	Reference Distance Increment SRDL (ft)	Conveyance K	Flow Top Width REW-LEW (ft)	Froude Number FR#	Other Losses HO (ft)	Velocity Head VHD (ft)
Cross Section Type CODE	Discharge Q (cfs)	Critical Flow Elevation CRWS (ft MSL)	Right Edge of Water REW (ft)	Flow Velocity VEL (ft/s)	Energy Balance Error ERR (ft)	Water Surface Elevation WSEL (ft MSL)
00001	*********	1558.5	28.47	1.243	*********	361.27
1000.00	*********	472804	221.74	.008	*********	.00
STANDARD	159	347.84	250.21	.102	*********	361.27

WARNING: (135) Conveyance ratio outside of recommended conveyance ratio limits.

Cross-Section ID Code (SECID) 00002
Computed Conveyance Ratio (KRATIO) 1.622

STATUS: (140) End of cross-section extended vertically.

Cross-Section ID code (SECID)	00002
Final Computed Water Surface Elevation (WSEL, ft MSL)	361.27
Left-Most Ground Elevation (YLT, ft MSL)	359.40
Right-Most Ground Elevation (YRT, ft MSL)	371.80

XSID	FLEN	AREA	LEW	ALPH	HF	EGL
SRD	SRDL	K	REW-LEW	FR#	HO	VHD
CODE	Q	CRWS	REW	VEL	ERR	WSEL
00002	30.00	2247.9	.00	1.375	.000	361.27
1030.00	30.00	766791	233.40	.005	.000	.00
STANDARD	159	*********	233.40	.071	.000	361.27

STATUS: (140) End of cross-section extended vertically.

Cross-Section ID code (SECID)	00003
Final Computed Water Surface Elevation (WSEL, ft MSL)	361.27
Left-Most Ground Elevation (YLT, ft MSL)	359.80
Right-Most Ground Elevation (YRT, ft MSL)	368.60

00003	30.00	2164.3	.00	1.380	.000	361.27
1060.00	30.00	786571	226.08	.005	.000	.00
STANDARD	159	*********	226.08	.073	.000	361.27

WARNING: (135) Conveyance ratio outside of recommended conveyance ratio limits.

Cross-Section ID Code (SECID)	00004
Computed Conveyance Ratio (KRATIO)	.151

00004	20.00	819.3	65.57	3.349	.000	361.27
1080.00	20.00	118837	151.58	.027	.001	.00
STANDARD	159	*********	217.16	.194	.000	361.27

WARNING: (135) Conveyance ratio outside of recommended conveyance ratio limits.

Cross-Section ID Code (SECID)	00005
Computed Conveyance Ratio (KRATIO)	.473

00005	9.00	396.2	113.13	1.724	.000	361.27
1089.00	9.00	56178	85.29	.043	.001	.00
FULVALLEY	159	*********	198.43	.401	.000	361.27

WARNING: (135) Conveyance ratio outside of recommended conveyance ratio limits.

Cross-Section ID Code (SECID) 00008
Computed Conveyance Ratio (KRATIO) 3.140

XSID / SRD / CODE	FLEN / SRDL / Q	AREA / K / CRWS	LEW / REW-LEW / REW	ALPH / FR# / VEL	HF / HO / ERR	EGL / VHD / WSEL
00008	36.00	916.0	80.30	1.933	.000	361.27
1125.00	36.00	176397	199.76	.020	.000	.00
APPROACH	159	*********	280.06	.174	.000	361.27

STATUS: The above results reflect NORMAL (unconstricted) flow.

STATUS: Results reflecting the constricted flow follow.

00006	9.00	50.3	165.50	1.226	.000	361.44
1089.00	9.00	9378	9.00	.237	.170	.19
BRIDGE	159	354.50	174.50	3.164	.000	361.25

Bridge Opening Type (TYPE)	2.
Column Type Code (PPCD)	**********
Flow Class (FLOW)	1.
Bridge Opening Discharge Coefficient (C)	.903
Ratio of Pier Area/Gross Bridge Area (P/A)	**********
Bridge Low Chord Elevation (LSEL, ft MSL)	363.30
Bridge Length (BLEN, ft)	**********
Left Abutment Toe Station (XLAB, ft)	**********
Right Abutment Toe Station (XRAB, ft)	**********

STATUS: Roadway embankment is not overtopped.

Error Code (ERRFLG)	NONE
Cross-Section ID Code (SECID)	00007
Cross-Section Type (XSCODE)	ROADGRADE
Cross-Section Reference Distance (SRD, ft)	1107.60

00008	14.36	952.4	78.40	1.962	.000	361.45
1125.00	8.85	184432	203.74	.019	.012	.00
APPROACH	159	352.74	282.14	.167	.001	361.45

Geometric Contraction Ratio (M(G)) .955
Flow Contraction Ratio (M(K)) .837
Kq-Section Conveyance (KQ) 29979.
Kq-Section Left Limit Station (XLKQ, ft) 163.77
Kq-Section Right Limit Station (XRKQ, ft) 172.77
Min Roadgrade Elevation Allowed w/o Overtopping (OTEL, ft MSL) 361.45

STATUS: End of bridge computations.

XSID	FLEN	AREA	LEW	ALPH	HF	EGL
SRD	SRDL	K	REW-LEW	FR#	HO	VHD
CODE	Q	CRWS	REW	VEL	ERR	WSEL
00009	29.00	1107.7	78.40	1.942	.000	361.45
1154.00	29.00	244512	203.75	.015	.000	.00
STANDARD	159	*********	282.14	.144	.000	361.45

PROFILE NUMBER 2 :

00001	*********	1605.4	25.79	1.257	*********	361.48
1000.00	*********	490462	225.04	.010	*********	.00
STANDARD	209	347.99	250.82	.130	*********	361.48

WARNING: (135) Conveyance ratio outside of recommended conveyance ratio limits.

Cross-Section ID Code (SECID) 00002
Computed Conveyance Ratio (KRATIO) 1.609

STATUS: (140) End of cross-section extended vertically.

Cross-Section ID code (SECID) 00002
Final Computed Water Surface Elevation (WSEL, ft MSL) 361.48
Left-Most Ground Elevation (YLT, ft MSL) 359.40
Right-Most Ground Elevation (YRT, ft MSL) 371.80

00002	30.00	2297.0	.00	1.382	.000	361.48
1030.00	30.00	789026	233.93	.006	.000	.00
STANDARD	209	*********	233.93	.091	.000	361.48

STATUS: (140) End of cross-section extended vertically.

Cross-Section ID code (SECID)	00003
Final Computed Water Surface Elevation (WSEL, ft MSL)	361.48
Left-Most Ground Elevation (YLT, ft MSL)	359.80
Right-Most Ground Elevation (YRT, ft MSL)	368.60

XSID	FLEN	AREA	LEW	ALPH	HF	EGL
SRD	SRDL	K	REW-LEW	FR#	HO	VHD
CODE	Q	CRWS	REW	VEL	ERR	WSEL
00003	30.00	2211.9	.00	1.391	.000	361.48
1060.00	30.00	807651	226.48	.006	.000	.00
STANDARD	209	*********	226.48	.094	.000	361.48

WARNING: (135) Conveyance ratio outside of recommended conveyance ratio limits.

Cross-Section ID Code (SECID)	00004
Computed Conveyance Ratio (KRATIO)	.154

00004	20.00	851.2	64.44	3.349	.000	361.48
1080.00	20.00	124497	153.72	.034	.001	.00
STANDARD	209	*********	218.16	.246	.000	361.48

WARNING: (135) Conveyance ratio outside of recommended conveyance ratio limits.

Cross-Section ID Code (SECID)	00005
Computed Conveyance Ratio (KRATIO)	.481

00005	9.00	414.3	111.91	1.742	.000	361.48
1089.00	9.00	59931	87.85	.054	.002	.01
FULVALLEY	209	*********	199.75	.505	.000	361.48

WARNING: (135) Conveyance ratio outside of recommended conveyance ratio limits.

Cross-Section ID Code (SECID)	00008
Computed Conveyance Ratio (KRATIO)	3.100

00008	36.00	958.6	78.08	1.967	.000	361.48
1125.00	36.00	185802	204.41	.025	.001	.00
APPROACH	209	*********	282.49	.218	.000	361.48

XSID	FLEN	AREA	LEW	ALPH	HF	EGL
SRD	SRDL	K	REW-LEW	FR#	HO	VHD
CODE	Q	CRWS	REW	VEL	ERR	WSEL
00006	9.00	51.7	165.50	1.227	.000	361.76
1089.00	9.00	9742	9.00	.298	.277	.31
BRIDGE	209	355.13	174.50	4.042	.000	361.45

STATUS: The above results reflect NORMAL (unconstricted) flow.

STATUS: Results reflecting the constricted flow follow.

00006	9.00	51.7	165.50	1.227	.000	361.76
1089.00	9.00	9742	9.00	.298	.277	.31
BRIDGE	209	355.13	174.50	4.042	.000	361.45

Bridge Opening Type (TYPE)	2.
Column Type Code (PPCD)	**********
Flow Class (FLOW)	1.
Bridge Opening Discharge Coefficient (C)	.903
Ratio of Pier Area/Gross Bridge Area (P/A)	**********
Bridge Low Chord Elevation (LSEL, ft MSL)	363.30
Bridge Length (BLEN, ft)	**********
Left Abutment Toe Station (XLAB, ft)	**********
Right Abutment Toe Station (XRAB, ft)	**********

STATUS: Roadway embankment is not overtopped.

Error Code (ERRFLG)	NONE
Cross-Section ID Code (SECID)	00007
Cross-Section Type (XSCODE)	ROADGRADE
Cross-Section Reference Distance (SRD, ft)	1107.60

00008	14.49	1019.7	74.98	2.014	.000	361.78
1125.00	8.85	199369	210.91	.023	.019	.00
APPROACH	209	352.97	285.89	.205	.003	361.78

Geometric Contraction Ratio (M(G))	.956
Flow Contraction Ratio (M(K))	.842
Kq-Section Conveyance (KQ)	31548.
Kq-Section Left Limit Station (XLKQ, ft)	163.93
Kq-Section Right Limit Station (XRKQ, ft)	172.93
Min Roadgrade Elevation Allowed w/o Overtopping (OTEL, ft MSL)	361.78

STATUS: End of bridge computations.

00009	29.00	1175.1	74.98	1.992	.000	361.78
1154.00	29.00	261011	210.91	.019	.000	.00
STANDARD	209	*********	285.89	.178	.000	361.78

PROFILE NUMBER 3 :

XSID	FLEN	AREA	LEW	ALPH	HF	EGL
SRD	SRDL	K	REW-LEW	FR#	HO	VHD
CODE	Q	CRWS	REW	VEL	ERR	WSEL
00001	*********	1637.1	24.00	1.267	*********	361.62
1000.00	*********	502408	227.24	.011	*********	.00
STANDARD	241	348.18	251.24	.147	*********	361.62

WARNING: (135) Conveyance ratio outside of recommended conveyance ratio limits.

Cross-Section ID Code (SECID) 00002
Computed Conveyance Ratio (KRATIO) 1.600

STATUS: (140) End of cross-section extended vertically.

Cross-Section ID code (SECID) 00002
Final Computed Water Surface Elevation (WSEL, ft MSL) 361.62
Left-Most Ground Elevation (YLT, ft MSL) 359.40
Right-Most Ground Elevation (YRT, ft MSL) 371.80

00002	30.00	2329.8	.00	1.387	.000	361.62
1030.00	30.00	803999	234.28	.007	.000	.00
STANDARD	241	*********	234.28	.103	.000	361.62

STATUS: (140) End of cross-section extended vertically.

Cross-Section ID code (SECID) 00003
Final Computed Water Surface Elevation (WSEL, ft MSL) 361.62
Left-Most Ground Elevation (YLT, ft MSL) 359.80
Right-Most Ground Elevation (YRT, ft MSL) 368.60

00003	30.00	2243.6	.00	1.398	.000	361.62
1060.00	30.00	821844	226.75	.007	.000	.00
STANDARD	241	*********	226.75	.107	.000	361.62

WARNING: (135) Conveyance ratio outside of recommended conveyance ratio limits.

Cross-Section ID Code (SECID) 00004
Computed Conveyance Ratio (KRATIO) .156

XSID	FLEN	AREA	LEW	ALPH	HF	EGL
SRD	SRDL	K	REW-LEW	FR#	HO	VHD
CODE	Q	CRWS	REW	VEL	ERR	WSEL
00004	20.00	872.8	63.69	3.349	.000	361.62
1080.00	20.00	128346	155.15	.038	.001	.00
STANDARD	241	*********	218.83	.276	.000	361.62

WARNING: (135) Conveyance ratio outside of recommended conveyance ratio limits.

Cross-Section ID Code (SECID) 00005
Computed Conveyance Ratio (KRATIO) .487

00005	9.00	426.6	111.09	1.755	.000	361.62
1089.00	9.00	62495	89.55	.060	.002	.01
FULVALLEY	241	*********	200.64	.565	.000	361.62

WARNING: (135) Conveyance ratio outside of recommended conveyance ratio limits.

Cross-Section ID Code (SECID) 00008
Computed Conveyance Ratio (KRATIO) 3.076

00008	36.00	987.6	76.60	1.989	.000	361.62
1125.00	36.00	192215	207.51	.028	.001	.00
APPROACH	241	*********	284.11	.244	.000	361.62

STATUS: The above results reflect NORMAL (unconstricted) flow.

STATUS: Results reflecting the constricted flow follow.

00006	9.00	52.7	165.50	1.227	.000	361.98
1089.00	9.00	9984	9.00	.334	.356	.40
BRIDGE	241	355.52	174.50	4.575	.000	361.58

Bridge Opening Type (TYPE)	2.
Column Type Code (PPCD)	**********
Flow Class (FLOW)	1.
Bridge Opening Discharge Coefficient (C)	.903
Ratio of Pier Area/Gross Bridge Area (P/A)	**********
Bridge Low Chord Elevation (LSEL, ft MSL)	363.30
Bridge Length (BLEN, ft)	**********
Left Abutment Toe Station (XLAB, ft)	**********
Right Abutment Toe Station (XRAB, ft)	**********

STATUS: Roadway embankment is not overtopped.

Error Code (ERRFLG)	NONE
Cross-Section ID Code (SECID)	00007
Cross-Section Type (XSCODE)	ROADGRADE
Cross-Section Reference Distance (SRD, ft)	1107.60

XSID	FLEN	AREA	LEW	ALPH	HF	EGL
SRD	SRDL	K	REW-LEW	FR#	HO	VHD
CODE	Q	CRWS	REW	VEL	ERR	WSEL
00008	14.58	1067.3	72.63	2.048	.000	362.00
1125.00	8.85	210001	215.83	.026	.024	.00
APPROACH	241	353.10	288.46	.226	.004	362.00

Geometric Contraction Ratio (M(G))	.957
Flow Contraction Ratio (M(K))	.844
Kq-Section Conveyance (KQ)	32661.
Kq-Section Left Limit Station (XLKQ, ft)	164.01
Kq-Section Right Limit Station (XRKQ, ft)	173.01
Min Roadgrade Elevation Allowed w/o Overtopping (OTEL, ft MSL)	362.00

STATUS: End of bridge computations.

00009	29.00	1222.7	72.63	2.026	.000	362.00
1154.00	29.00	272707	215.84	.021	.000	.00
STANDARD	241	*********	288.47	.197	.000	362.00

PROFILE NUMBER 4 :

00001	*********	1662.2	22.60	1.275	*********	361.73
1000.00	*********	511896	228.96	.013	*********	.00
STANDARD	283	348.18	251.56	.170	*********	361.73

WARNING: (135) Conveyance ratio outside of recommended conveyance ratio limits.

Cross-Section ID Code (SECID)	00002
Computed Conveyance Ratio (KRATIO)	1.594

STATUS: (140) End of cross-section extended vertically.

Cross-Section ID code (SECID) 00002
Final Computed Water Surface Elevation (WSEL, ft MSL) 361.73
Left-Most Ground Elevation (YLT, ft MSL) 359.40
Right-Most Ground Elevation (YRT, ft MSL) 371.80

XSID	FLEN	AREA	LEW	ALPH	HF	EGL
SRD	SRDL	K	REW-LEW	FR#	HO	VHD
CODE	Q	CRWS	REW	VEL	ERR	WSEL
00002	30.00	2355.6	.00	1.391	.000	361.73
1030.00	30.00	815861	234.56	.008	.000	.00
STANDARD	283	*********	234.56	.120	.000	361.73

STATUS: (140) End of cross-section extended vertically.

Cross-Section ID code (SECID) 00003
Final Computed Water Surface Elevation (WSEL, ft MSL) 361.73
Left-Most Ground Elevation (YLT, ft MSL) 359.80
Right-Most Ground Elevation (YRT, ft MSL) 368.60

00003	30.00	2268.6	.00	1.403	.000	361.73
1060.00	30.00	833084	226.96	.008	.000	.00
STANDARD	283	*********	226.96	.125	.000	361.73

WARNING: (135) Conveyance ratio outside of recommended conveyance ratio limits.

Cross-Section ID Code (SECID) 00004
Computed Conveyance Ratio (KRATIO) .158

00004	20.00	889.8	63.10	3.349	.000	361.73
1080.00	20.00	131405	156.26	.043	.001	.01
STANDARD	283	*********	219.36	.318	.000	361.73

WARNING: (135) Conveyance ratio outside of recommended conveyance ratio limits.

Cross-Section ID Code (SECID) 00005
Computed Conveyance Ratio (KRATIO) .491

00005	9.00	436.4	110.45	1.765	.000	361.74
1089.00	9.00	64534	90.88	.069	.003	.01
FULVALLEY	283	*********	201.33	.649	.000	361.72

WARNING: (135) Conveyance ratio outside of recommended conveyance ratio limits.

Cross-Section ID Code (SECID)	00008
Computed Conveyance Ratio (KRATIO)	3.058

XSID / SRD / CODE	FLEN / SRDL / Q	AREA / K / CRWS	LEW / REW-LEW / REW	ALPH / FR# / VEL	HF / HO / ERR	EGL / VHD / WSEL
00008	36.00	1010.7	75.43	2.007	.000	361.74
1125.00	36.00	197363	209.96	.032	.001	.00
APPROACH	283	*********	285.39	.280	.000	361.73

STATUS: The above results reflect NORMAL (unconstricted) flow.

STATUS: Results reflecting the constricted flow follow.

00006	9.00	53.4	165.50	1.227	.001	362.21
1089.00	9.00	10162	9.00	.385	.478	.54
BRIDGE	283	355.99	174.50	5.301	.000	361.67

Bridge Opening Type (TYPE)	2.
Column Type Code (PPCD)	**********
Flow Class (FLOW)	1.
Bridge Opening Discharge Coefficient (C)	.903
Ratio of Pier Area/Gross Bridge Area (P/A)	**********
Bridge Low Chord Elevation (LSEL, ft MSL)	363.30
Bridge Length (BLEN, ft)	**********
Left Abutment Toe Station (XLAB, ft)	**********
Right Abutment Toe Station (XRAB, ft)	**********

STATUS: Roadway embankment is not overtopped.

Error Code (ERRFLG)	NONE
Cross-Section ID Code (SECID)	00007
Cross-Section Type (XSCODE)	ROADGRADE
Cross-Section Reference Distance (SRD, ft)	1107.60

00008	14.65	1119.8	70.11	2.084	.001	362.24
1125.00	8.85	221768	221.12	.029	.031	.00
APPROACH	283	353.25	291.23	.253	.007	362.24

Geometric Contraction Ratio (M(G)) .957
Flow Contraction Ratio (M(K)) .847
Kq-Section Conveyance (KQ) 33860.
Kq-Section Left Limit Station (XLKQ, ft) 164.09
Kq-Section Right Limit Station (XRKQ, ft) 173.09
Min Roadgrade Elevation Allowed w/o Overtopping (OTEL, ft MSL) 362.24

STATUS: End of bridge computations.

XSID	FLEN	AREA	LEW	ALPH	HF	EGL
SRD	SRDL	K	REW-LEW	FR#	HO	VHD
CODE	Q	CRWS	REW	VEL	ERR	WSEL
00009	29.00	1275.1	70.10	2.063	.000	362.24
1154.00	29.00	285612	221.14	.023	.000	.00
STANDARD	283	*********	291.24	.222	.000	362.24

PROFILE NUMBER 5 :

00001	*********	1650.7	23.23	1.271	*********	361.68
1000.00	*********	507572	228.18	.021	*********	.00
STANDARD	480	348.68	251.41	.291	*********	361.68

WARNING: (135) Conveyance ratio outside of recommended conveyance ratio limits.

Cross-Section ID Code (SECID) 00002
Computed Conveyance Ratio (KRATIO) 1.597

STATUS: (140) End of cross-section extended vertically.

Cross-Section ID code (SECID) 00002
Final Computed Water Surface Elevation (WSEL, ft MSL) 361.68
Left-Most Ground Elevation (YLT, ft MSL) 359.40
Right-Most Ground Elevation (YRT, ft MSL) 371.80

00002	*30.00*	*2344.0*	*.00*	*1.389*	*.000*	*361.68*
1030.00	30.00	810522	234.44	.013	.000	.00
STANDARD	480	*********	234.44	.205	.000	361.68

STATUS: (140) End of cross-section extended vertically.

Cross-Section ID code (SECID) 00003
Final Computed Water Surface Elevation (WSEL, ft MSL) 361.68
Left-Most Ground Elevation (YLT, ft MSL) 359.80
Right-Most Ground Elevation (YRT, ft MSL) 368.60

XSID	FLEN	AREA	LEW	ALPH	HF	EGL
SRD	SRDL	K	REW-LEW	FR#	HO	VHD
CODE	Q	CRWS	REW	VEL	ERR	WSEL
00003	30.00	2257.3	.00	1.401	.000	361.68
1060.00	30.00	828024	226.86	.014	.000	.00
STANDARD	480	*********	226.86	.213	.000	361.68

WARNING: (135) Conveyance ratio outside of recommended conveyance ratio limits.

Cross-Section ID Code (SECID) 00004
Computed Conveyance Ratio (KRATIO) .157

00004	20.00	881.0	63.40	3.349	.000	361.69
1080.00	20.00	129829	155.69	.074	.004	.02
STANDARD	480	*********	219.09	.545	.000	361.67

WARNING: (135) Conveyance ratio outside of recommended conveyance ratio limits.

Cross-Section ID Code (SECID) 00005
Computed Conveyance Ratio (KRATIO) .488

00005	9.00	430.8	110.81	1.760	.000	361.70
1089.00	9.00	63363	90.12	.119	.009	.03
FULVALLEY	480	*********	200.93	1.114	.000	361.66

WARNING: (135) Conveyance ratio outside of recommended conveyance ratio limits.

Cross-Section ID Code (SECID) 00008
Computed Conveyance Ratio (KRATIO) 3.098

00008	36.00	1006.0	75.67	2.003	.001	361.72
1125.00	36.00	196324	209.47	.054	.003	.01
APPROACH	480	*********	285.14	.477	.020	361.71

XSID	FLEN	AREA	LEW	ALPH	HF	EGL
SRD	SRDL	K	REW-LEW	FR#	HO	VHD
CODE	Q	CRWS	REW	VEL	ERR	WSEL
00006	9.00	52.2	165.50	1.229	.002	363.13
1089.00	9.00	9866	9.00	.675	1.442	1.62
BRIDGE	480	357.97	174.50	9.195	.000	361.51

STATUS: The above results reflect NORMAL (unconstricted) flow.

STATUS: Results reflecting the constricted flow follow.

Bridge Opening Type (TYPE)	2.
Column Type Code (PPCD)	**********
Flow Class (FLOW)	1.
Bridge Opening Discharge Coefficient (C)	.902
Ratio of Pier Area/Gross Bridge Area (P/A)	**********
Bridge Low Chord Elevation (LSEL, ft MSL)	363.30
Bridge Length (BLEN, ft)	**********
Left Abutment Toe Station (XLAB, ft)	**********
Right Abutment Toe Station (XRAB, ft)	**********

STATUS: Roadway embankment is not overtopped.

Error Code (ERRFLG)	NONE
Cross-Section ID Code (SECID)	00007
Cross-Section Type (XSCODE)	ROADGRADE
Cross-Section Reference Distance (SRD, ft)	1107.60

STATUS: (140) End of cross-section extended vertically.

Cross-Section ID code (SECID)	00008
Final Computed Water Surface Elevation (WSEL, m MSL)	363.22
Left-Most Ground Elevation (YLT, m MSL)	367.10
Right-Most Ground Elevation (YRT, m MSL)	363.00

00008	14.64	1346.0	59.74	2.217	.001	363.22
1125.00	*8.85*	*273733*	*240.26*	*.040*	*.090*	*.00*
APPROACH	480	353.89	300.00	.357	.001	363.22

Geometric Contraction Ratio (M(G)) .957
Flow Contraction Ratio (M(K)) .856
Kq-Section Conveyance (KQ) 39282.
Kq-Section Left Limit Station (XLKQ, ft) 164.07
Kq-Section Right Limit Station (XRKQ, ft) 173.07
Min Roadgrade Elevation Allowed w/o Overtopping (OTEL, ft MSL) 363.22

STATUS: End of bridge computations.

STATUS: (140) End of cross-section extended vertically.

Cross-Section ID code (SECID) 00009
Final Computed Water Surface Elevation (WSEL, ft MSL) 363.22
Left-Most Ground Elevation (YLT, ft MSL) 367.10
Right-Most Ground Elevation (YRT, ft MSL) 363.00

XSID	FLEN	AREA	LEW	ALPH	HF	EGL
SRD	SRDL	K	REW-LEW	FR#	HO	VHD
CODE	Q	CRWS	REW	VEL	ERR	WSEL
00009	*29.00*	*1501.5*	*59.73*	*2.199*	*.000*	*363.22*
1154.00	29.00	342158	240.27	.033	.000	.00
STANDARD	480	*********	300.00	.320	.000	363.22

PROFILE NUMBER 6 :

00001	*********	2202.7	.00	1.423	*********	363.93
1000.00	*********	720967	258.03	.020	*********	.00
STANDARD	610	348.96	258.03	.277	*********	363.93

WARNING: (135) Conveyance ratio outside of recommended conveyance ratio limits.

Cross-Section ID Code (SECID) 00002
Computed Conveyance Ratio (KRATIO) 1.482

STATUS: (140) End of cross-section extended vertically.

Cross-Section ID code (SECID) 00002
Final Computed Water Surface Elevation (WSEL, ft MSL) 363.93
Left-Most Ground Elevation (YLT, ft MSL) 359.40
Right-Most Ground Elevation (YRT, ft MSL) 371.80

XSID	FLEN	AREA	LEW	ALPH	HF	EGL
SRD	SRDL	K	REW-LEW	FR#	HO	VHD
CODE	Q	CRWS	REW	VEL	ERR	WSEL
00002	30.00	2877.9	.00	1.452	.000	363.93
1030.00	30.00	1068592	240.12	.013	.000	.00
STANDARD	610	*********	240.12	.212	.000	363.93

STATUS: (140) End of cross-section extended vertically.

Cross-Section ID code (SECID) 00003
Final Computed Water Surface Elevation (WSEL, ft MSL) 363.93
Left-Most Ground Elevation (YLT, ft MSL) 359.80
Right-Most Ground Elevation (YRT, ft MSL) 368.60

00003	30.00	2772.6	.00	1.488	.000	363.93
1060.00	30.00	1072412	231.13	.014	.000	.00
STANDARD	610	*********	231.13	.220	.000	363.93

WARNING: (135) Conveyance ratio outside of recommended conveyance ratio limits.

Cross-Section ID Code (SECID) 00004
Computed Conveyance Ratio (KRATIO) .178

STATUS: (140) End of cross-section extended vertically.

Cross-Section ID code (SECID) 00004
Final Computed Water Surface Elevation (WSEL, ft MSL) 363.92
Left-Most Ground Elevation (YLT, ft MSL) 363.70
Right-Most Ground Elevation (YRT, ft MSL) 368.10

00004	20.00	1305.6	.00	4.108	.000	363.94
1080.00	20.00	191134	229.91	.070	.004	.01
STANDARD	610	*********	229.91	.467	.000	363.92

WARNING: (135) Conveyance ratio outside of recommended conveyance ratio limits.

Cross-Section ID Code (SECID) 00005
Computed Conveyance Ratio (KRATIO) .560

STATUS: (140) End of cross-section extended vertically.

Cross-Section ID code (SECID)	00005
Final Computed Water Surface Elevation (WSEL, ft MSL)	363.91
Left-Most Ground Elevation (YLT, ft MSL)	363.20
Right-Most Ground Elevation (YRT, ft MSL)	371.00

XSID	FLEN	AREA	LEW	ALPH	HF	EGL
SRD	SRDL	K	REW-LEW	FR#	HO	VHD
CODE	Q	CRWS	REW	VEL	ERR	WSEL
00005	9.00	767.1	.00	3.045	.000	363.94
1089.00	9.00	107061	215.23	.130	.008	.03
FULVALLEY	610	*********	215.23	.795	.000	363.91

WARNING: (135) Conveyance ratio outside of recommended conveyance ratio limits.

Cross-Section ID Code (SECID)	00008
Computed Conveyance Ratio (KRATIO)	2.956

STATUS: (140) End of cross-section extended vertically.

Cross-Section ID code (SECID)	00008
Final Computed Water Surface Elevation (WSEL, ft MSL)	363.94
Left-Most Ground Elevation (YLT, ft MSL)	367.10
Right-Most Ground Elevation (YRT, ft MSL)	363.00

00008	36.00	1524.1	48.60	2.292	.000	363.95
1125.00	36.00	316502	251.40	.043	.002	.01
APPROACH	610	*********	300.00	.400	.000	363.94

STATUS: (255) Attempting flow class 3 (or 6) solution.

Full Valley Water Surface Elevation (WS3N, ft MSL)	363.91
Bridge Low-Chord Elevation (LSEL, ft MSL)	363.30

WARNING: (265) Road overflow appears excessive.

Road Overflow (QRD, cfs)	176.04
Maximum Road Overflow (QRDMAX, cfs)	120.86
Road Overflow Ratio (QRD/QRDMAX)	1.46

XSID	FLEN	AREA	LEW	ALPH	HF	EGL
SRD	SRDL	K	REW-LEW	FR#	HO	VHD
CODE	Q	CRWS	REW	VEL	ERR	WSEL
00006	*********	65.4	165.50	1.000	*********	363.99
1089.00	9.00	11192	9.00	.435	*********	.69
BRIDGE	435	357.55	174.50	6.652	*********	363.30

STATUS: The above results reflect NORMAL (unconstricted) flow.

STATUS: Results reflecting the constricted flow follow.

Bridge Opening Type (TYPE)	2.
Column Type Code (PPCD)	**********
Flow Class (FLOW)	6.
Bridge Opening Discharge Coefficient (C)	.800
Ratio of Pier Area/Gross Bridge Area (P/A)	**********
Bridge Low Chord Elevation (LSEL, ft MSL)	363.30
Bridge Length (BLEN, ft)	**********
Left Abutment Toe Station (XLAB, ft)	**********
Right Abutment Toe Station (XRAB, ft)	**********

Cross-Section ID Code	00007
Cross-Section Type (CODE)	ROADGRADE
Section Reference Distance (SRD, ft)	1107.60
Flow Length (FLEN, ft)	8.85
Friction Loss (HF, ft)	.000
Velocity Head (VHD, ft)	.004
Energy Gradeline Elevation (EGL, ft MSL)	364.99
Energy Balance Error (ERR, ft)	.00
Discharge (Q, cfs)	176.
Computed Water Surface Elevation (WSEL, ft MSL)	364.79

Overflow Results for Left Side of Roadway

Discharge (Q, cfs)	167.
Road Overflow Weir Length (WLEN, ft)	79.15
Left Edge of Water (LEW, ft)	72.05
Right Edge of Water (REW, ft)	168.68
Maximum Weir Flow Depth (DMAX, ft)	.99
Average Weir Flow Depth (DAVG, ft)	.62
Estimated Maximum Road Overflow Velocity (VMAX, ft/s)	3.863
Average Road Overflow Velocity (VAVG, ft/s)	3.395
Average Total Head for Weir Flow (HAVG, ft)	.82
Average Weir Coefficient (CAVG)	2.843

Overflow Results for Right Side of Roadway

Discharge (Q, cfs)	9.
Road Overflow Weir Length (WLEN, ft)	12.84
Left Edge of Water (LEW, ft)	168.68
Right Edge of Water (REW, ft)	184.35
Maximum Weir Flow Depth (DMAX, ft)	.32
Average Weir Flow Depth (DAVG, ft)	.20
Estimated Maximum Road Overflow Velocity (VMAX, ft/s)	2.559
Average Road Overflow Velocity (VAVG, ft/s)	2.559
Average Total Head for Weir Flow (HAVG, ft)	.40
Average Weir Coefficient (CAVG)	2.704

STATUS: (140) End of cross-section extended vertically.

Cross-Section ID code (SECID)	00008
Final Computed Water Surface Elevation (WSEL, m MSL)	364.98
Left-Most Ground Elevation (YLT, m MSL)	367.10
Right-Most Ground Elevation (YRT, m MSL)	363.00

XSID	FLEN	AREA	LEW	ALPH	HF	EGL
SRD	SRDL	K	REW-LEW	FR#	HO	VHD
CODE	Q	CRWS	REW	VEL	ERR	WSEL
00008	15.96	1794.7	32.55	2.385	.001	364.99
1125.00	8.85	383992	267.45	.036	.090	.00
APPROACH	610	354.22	300.00	.340	.001	364.98

Geometric Contraction Ratio (M(G))	**********
Flow Contraction Ratio (M(K))	**********
Kq-Section Conveyance (KQ)	**********
Kq-Section Left Limit Station (XLKQ, ft)	**********
Kq-Section Right Limit Station (XRKQ, ft)	**********
Min Roadgrade Elevation Allowed w/o Overtopping (OTEL, ft MSL)	**********

STATUS: End of bridge computations.

STATUS: (140) End of cross-section extended vertically.

Cross-Section ID code (SECID)	00009
Final Computed Water Surface Elevation (WSEL, ft MSL)	364.99
Left-Most Ground Elevation (YLT, ft MSL)	367.10
Right-Most Ground Elevation (YRT, ft MSL)	363.00

00009	29.00	1950.2	32.54	2.385	.000	364.99
1154.00	29.00	460280	267.46	.032	.000	.00
STANDARD	610	*********	300.00	.313	.000	364.99

PROFILE NUMBER 7 :

XSID	FLEN	AREA	LEW	ALPH	HF	EGL
SRD	SRDL	K	REW-LEW	FR#	HO	VHD
CODE	Q	CRWS	REW	VEL	ERR	WSEL
00001	*********	2551.1	.00	1.484	*********	365.28
1000.00	*********	867450	261.97	.049	*********	.01
STANDARD	1820	350.77	261.97	.713	*********	365.27

WARNING: (135) Conveyance ratio outside of recommended conveyance ratio limits.

Cross-Section ID Code (SECID)	00002
Computed Conveyance Ratio (KRATIO)	1.426

STATUS: (140) End of cross-section extended vertically.

Cross-Section ID code (SECID)	00002
Final Computed Water Surface Elevation (WSEL, ft MSL)	365.27
Left-Most Ground Elevation (YLT, ft MSL)	359.40
Right-Most Ground Elevation (YRT, ft MSL)	371.80

00002	30.00	3202.9	.00	1.482	.000	365.28
1030.00	30.00	1237201	243.52	.034	.000	.01
STANDARD	1820	*********	243.52	.568	.000	365.27

STATUS: (140) End of cross-section extended vertically.

Cross-Section ID code (SECID)	00003
Final Computed Water Surface Elevation (WSEL, ft MSL)	365.27
Left-Most Ground Elevation (YLT, ft MSL)	359.80
Right-Most Ground Elevation (YRT, ft MSL)	368.60

00003	30.00	3084.8	.00	1.527	.000	365.28
1060.00	30.00	1231741	233.69	.035	.000	.01
STANDARD	1820	*********	233.69	.590	.000	365.27

WARNING: (135) Conveyance ratio outside of recommended conveyance ratio limits.

Cross-Section ID Code (SECID)	00004
Computed Conveyance Ratio (KRATIO)	.202

STATUS: (140) End of cross-section extended vertically.

Cross-Section ID code (SECID)	00004
Final Computed Water Surface Elevation (WSEL, ft MSL)	365.22
Left-Most Ground Elevation (YLT, ft MSL)	363.70
Right-Most Ground Elevation (YRT, ft MSL)	368.10

XSID	FLEN	AREA	LEW	ALPH	HF	EGL
SRD	SRDL	K	REW-LEW	FR#	HO	VHD
CODE	Q	CRWS	REW	VEL	ERR	WSEL
00004	20.00	1609.1	.00	3.852	.000	365.30
1080.00	20.00	248668	236.17	.150	.021	.08
STANDARD	1820	*********	236.17	1.131	-.002	365.22

WARNING: (135) Conveyance ratio outside of recommended conveyance ratio limits.

Cross-Section ID Code (SECID)	00005
Computed Conveyance Ratio (KRATIO)	.617

STATUS: (140) End of cross-section extended vertically.

Cross-Section ID code (SECID)	00005
Final Computed Water Surface Elevation (WSEL, ft MSL)	365.17
Left-Most Ground Elevation (YLT, ft MSL)	363.20
Right-Most Ground Elevation (YRT, ft MSL)	371.00

00005	9.00	1043.5	.00	3.021	.001	365.32
1089.00	9.00	153442	223.23	.247	.033	.14
FULVALLEY	1820	*********	223.23	1.744	-.018	365.17

WARNING: (135) Conveyance ratio outside of recommended conveyance ratio limits.

Cross-Section ID Code (SECID)	00008
Computed Conveyance Ratio (KRATIO)	2.642

STATUS: (140) End of cross-section extended vertically.

Cross-Section ID code (SECID)	00008
Final Computed Water Surface Elevation (WSEL, ft MSL)	365.29
Left-Most Ground Elevation (YLT, ft MSL)	367.10
Right-Most Ground Elevation (YRT, ft MSL)	363.00

XSID	FLEN	AREA	LEW	ALPH	HF	EGL
SRD	SRDL	K	REW-LEW	FR#	HO	VHD
CODE	Q	CRWS	REW	VEL	ERR	WSEL
00008	36.00	1878.5	27.77	2.410	.002	365.33
1125.00	36.00	405415	272.23	.101	.011	.04
APPROACH	1820	*********	300.00	.969	.000	365.29

STATUS: (255) Attempting flow class 3 (or 6) solution.

Full Valley Water Surface Elevation (WS3N, ft MSL)	365.17
Bridge Low-Chord Elevation (LSEL, ft MSL)	363.30

WARNING: (265) Road overflow appears excessive.

Road Overflow (QRD, cfs)	1281.67
Maximum Road Overflow (QRDMAX, cfs)	707.28
Road Overflow Ratio (QRD/QRDMAX)	1.81

STATUS: The above results reflect NORMAL (unconstricted) flow.

STATUS: Results reflecting the constricted flow follow.

00006	*********	65.4	165.50	1.000	*********	364.24
1089.00	9.00	11192	9.00	.508	*********	.94
BRIDGE	508	358.23	174.50	7.772	*********	363.30

Bridge Opening Type (TYPE)	2.
Column Type Code (PPCD)	**********
Flow Class (FLOW)	6.
Bridge Opening Discharge Coefficient (C)	.800
Ratio of Pier Area/Gross Bridge Area (P/A)	**********
Bridge Low Chord Elevation (LSEL, ft MSL)	363.30
Bridge Length (BLEN, ft)	**********
Left Abutment Toe Station (XLAB, ft)	**********
Right Abutment Toe Station (XRAB, ft)	**********

Cross-Section ID Code	00007
Cross-Section Type (CODE)	ROADGRADE
Section Reference Distance (SRD, ft)	1107.60
Flow Length (FLEN, ft)	8.85
Friction Loss (HF, ft)	.000
Velocity Head (VHD, ft)	.025
Energy Gradeline Elevation (EGL, ft MSL)	366.64
Energy Balance Error (ERR, ft)	-.02
Discharge (Q, cfs)	1282.
Computed Water Surface Elevation (WSEL, ft MSL)	366.17

Overflow Results for Left Side of Roadway

Discharge (Q, cfs)	1063.
Road Overflow Weir Length (WLEN, ft)	116.00
Left Edge of Water (LEW, ft)	27.07
Right Edge of Water (REW, ft)	168.68
Maximum Weir Flow Depth (DMAX, ft)	2.37
Average Weir Flow Depth (DAVG, ft)	1.59
Estimated Maximum Road Overflow Velocity (VMAX, ft/s)	6.676
Average Road Overflow Velocity (VAVG, ft/s)	5.781
Average Total Head for Weir Flow (HAVG, ft)	2.06
Average Weir Coefficient (CAVG)	3.101

Overflow Results for Right Side of Roadway

Discharge (Q, cfs)	219.
Road Overflow Weir Length (WLEN, ft)	37.84
Left Edge of Water (LEW, ft)	168.68
Right Edge of Water (REW, ft)	214.87
Maximum Weir Flow Depth (DMAX, ft)	1.70
Average Weir Flow Depth (DAVG, ft)	1.06
Estimated Maximum Road Overflow Velocity (VMAX, ft/s)	5.648
Average Road Overflow Velocity (VAVG, ft/s)	5.449
Average Total Head for Weir Flow (HAVG, ft)	1.53
Average Weir Coefficient (CAVG)	3.040

STATUS: (140) End of cross-section extended vertically.

Cross-Section ID code (SECID)	00008
Final Computed Water Surface Elevation (WSEL, m MSL)	366.62
Left-Most Ground Elevation (YLT, m MSL)	367.10
Right-Most Ground Elevation (YRT, m MSL)	363.00

XSID	FLEN	AREA	LEW	ALPH	HF	EGL
SRD	SRDL	K	REW-LEW	FR#	HO	VHD
CODE	Q	CRWS	REW	VEL	ERR	WSEL
00008	16.76	2252.4	7.41	2.505	.004	366.64
1125.00	8.85	503633	292.59	.081	.090	.03
APPROACH	1820	356.41	300.00	.808	-.017	366.62

Geometric Contraction Ratio (M(G)) **********
Flow Contraction Ratio (M(K)) **********
Kq-Section Conveyance (KQ) **********
Kq-Section Left Limit Station (XLKQ, ft) **********
Kq-Section Right Limit Station (XRKQ, ft) **********
Min Roadgrade Elevation Allowed w/o Overtopping (OTEL, ft MSL) **********

STATUS: End of bridge computations.

STATUS: (140) End of cross-section extended vertically.

Cross-Section ID code (SECID) 00009
Final Computed Water Surface Elevation (WSEL, ft MSL) 366.62
Left-Most Ground Elevation (YLT, ft MSL) 367.10
Right-Most Ground Elevation (YRT, ft MSL) 363.00

00009	29.00	2408.7	7.35	2.522	.000	366.64
1154.00	29.00	587209	292.65	.074	.000	.02
STANDARD	1820	*********	300.00	.756	.000	366.62

ER

END OF OUTPUT

APPENDIX C

Scour Computations Using FHWA "HY-9"

CHOATE BROOK BRIDGE SCOUR COMPUTATION USING FHWA HY-9

****

CONTRACTION SCOUR

CASE 1 Overbank flow on a flood plain being forced back to the main channel by the Bridge.

$$\frac{y_2}{y_1} = \left(\frac{Q_{mc2}}{Q_{mc1}}\right)^{\frac{6}{7}} \left(\frac{W_{c1}}{W_{c2}}\right)^{k1} \left(\frac{n2}{n1}\right)^{k2} \quad \ldots\ldots\ldots\ldots (1)$$

$$y_{cs} = y_2 - y_1 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

1	flow depth @ approach	y_1	= 11.0 ft
2	width @ approach	w_1	= 40 ft
3	width @ constriction	w_2	= 6 ft
4	contracted flow	Q_{mc2}	= 480 cfs
5	main channel flow @ approach	Q_{mc1}	= 322 cfs
6	shear velocity/fall velocity	V_*/w	= 0.07
7	Manning n ratio (contracted/approach)		= 1.0
8	coefficient.	k_1	= 0.59
9	coefficient	k_2	= 0.066

RESULTS:

FLOW DEPTH AT Bridge OPENING y_2 = 47.3 ft

CONTRACTION SCOUR DEPTH y_{cs} = 36.3 ft

****